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HYPNOSIS, ATTENTION AND ATTENTION DEFICITS

PERSPECTIVES FROM BRAIN FUNCTIONS, BEHAVIORAL PERFORMANCE AND CLINICAL APPLICATIONS

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Hypnosis, attention and attention deficits

Perspectives from brain functions, behavioral performance and clinical applications

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DOCTORAL DISSERTATION

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ABSTRACT

Background. The present thesis combines studies on hypnosis, attention, and attention deficits from various perspectives to extend our understanding of hypnosis and its applications. This thesis includes experimental and clinical research of hypnosis from the perspectives of brain functions, behavioral performance, and clinical interventions. This thesis investigated whether brain oscillations, pre-attentive auditory information processing, auditory attentional performance, and deficits of attention can be influenced by hypnosis and hypnotic suggestions. Two studies focused on highly hypnotizable healthy participants, one study compared adults with attention deficit hyperactivity disorder (ADHD) to control participants, and one investigated solely adults with ADHD.

Aims. The present thesis examined: 1) whether hypnosis differs from the wake state as measured with the spectral power density of electroencephalography (EEG); 2) whether hypnosis and hypnotic suggestions can be used to influence bottom-up and/or top-down auditory attention. The former was indexed by the pre-attentive mismatch negativity (MMN) component of the auditory event-related potential (ERP). The latter was measured as the performance on a Continuous Performance Test (CPT); 3) whether hypnotherapy and hypnotic suggestions can be applied to adults with ADHD to relieve their symptoms in a long-lasting way, and to improve their attentional performance in an auditory reaction time task requiring sustained voluntary attention.

Methods. The present thesis applied various methods for investigating the research aims: EEG (Studies I–II), behavioral reaction time task (Study III) and self-report measures for evaluating the follow-up results of two individual psychological treatments, hypnotherapy and cognitive behavioral therapy (CBT) in ADHD adults (Study IV). The first three studies had a similar procedural structure including four experimental conditions: 1) pre-hypnosis, 2) after a hypnotic induction (i.e., neutral hypnosis), 3) hypnotic-suggestion condition with study-specific suggestions and 4) post-hypnosis. The first and second studies included a common EEG experiment with nine highly hypnotizable participants. In the first study, EEG spectral power was measured and analyzed at ten frontal, central, and posterior/occipital electrodes. In the second study, the MMN was recorded at three frontal electrodes using a passive oddball paradigm with sinusoidal standard (500 Hz) and deviant (520 Hz) tone stimuli. Both studies included in the hypnotic-suggestion condition suggestions aimed at altering the tone perception (“all tones sound similar in pitch”). The third study examined, in adults with ADHD and in healthy control participants, whether hypnotic suggestions can influence performance in a three-minute version of the auditory CPT. The suggestions aimed at improving speed and accuracy. The fourth study used a controlled, randomized design in investigating the effectiveness of hypnotherapy in treating adults with ADHD. It compared the six-month follow-up outcome of the hypnotherapy with the outcome of a short CBT in various self-report symptom scales.

Repeated-measures analysis of variance and t-tests were used in the statistical analysis of the studies.

Results. The results of Study I revealed no EEG power changes between pre-hypnosis and hypnosis conditions, challenging the current understanding that the increase of theta power is a marker of the hypnosis state. Contrary to the results of a few earlier studies, no statistically significant differences in the MMN amplitudes between the conditions were found in Study II, indicating that the auditory pre-attentive processing may not be influenced by hypnosis or hypnotic suggestions. Study III indicated that hypnotic suggestions have an effect on the reaction times in the CPT both in ADHD adults and healthy control participants. Study IV revealed that the treatment benefits remained during the six-month follow-up with both hypnotherapy and CBT groups when measured with self-report ADHD symptom scales. The benefits of hypnotherapy and CBT, however, differed in general psychological well-being, anxiety and depression, and approached significance in the ADHD symptoms scale, indicating a better long-term outcome for hypnotherapy.

Conclusion. Results of the present thesis indicate that: 1) the spectral power of EEG in the theta band cannot be used as a reliable marker of the hypnotic state in highly hypnotizable participants; 2) hypnotic suggestions can be used to influence performance in a sustained attention reaction time task, but they do not modulate the early pre-attentive auditory information processing, reflected by MMN; 3) hypnosis, hypnotic suggestions, and short hypnotherapy treatments can be successfully applied to adults with ADHD to improve their performance in a sustained attention reaction time task, and to reduce their ADHD and other symptoms in a long-lasting (at least half a year) way. Thus, hypnosis/hypnotherapy seems to be a usable treatment method for the ADHD adult population.

TIIVISTELMÄ

Tausta. Tämä väitöskirja yhdistää kolme laajaa tutkimusaluetta: hypnoosin, tarkkaavuuden ja tarkkaavuuden vaikeudet, tavoitteenaan saada lisätietoa hypnoosista, sen vaikutusmekanismeista ja sovellusmahdollisuuksista. Tutkimus käsittää sekä kokeellista perustutkimusta että kliinistä terapiatutkimusta ja hyödyntää monipuolisesti aivosähköisiä ja behavioraalisia mittausmenetelmiä, sekä terapiatutkimuksen vakiintuneita arviointimenetelmiä. Tutkimuksessa pyritään selvittämään, voidaanko hypnoosilla ja siihen liittyvillä suggestioilla vaikuttaa aivojen jännitevasteisiin, auditiivisen tarkkaavaisuuden tiettyihin vaiheisiin, ja voiko hypnoosia ja hypnoterapiaa käyttää aktiivisuuden ja tarkkaavuuden häiriöstä (ADHD) kärsivillä aikuisilla. Kahdessa ensimmäisessä osatutkimuksessa osallistujat olivat hypnoosiherkkiä aikuisia, kolmannessa osatutkimuksessa sekä ADHD-aikuisia että terveitä aikuisia, ja neljännessä osatutkimuksessa ADHD-aikuisia.

Tutkimuskysymykset. Tutkimuskysymykset ovat: 1) eroaako hypnoosin aivosähköisillä mittausmenetelmillä (elektroenkefalografia, EEG) laskettu tehotiheys eri taajuuskaistoilla normaalin valvetilan tehotiheydestä, 2) voidaanko hypnoosilla ja hypnoosisuggestioilla vaikuttaa toisaalta aivojen poikkeavuusnegatiivisuusvasteen (mismatch negativity, MMN) heijastamaan automaattiseen alhaalta ylös (bottom-up) tietojenkäsittelyyn ja toisaalta tahdonalaiseen ylhäältä alas (top-down) tiedonkäsittelyyn jatkuvaa tarkkaavuuden ylläpitoa vaativassa testissä (Continuous Performance Test, CPT), 3) voiko hypnoosia ja suggestioita käyttää ADHD-aikuisilla lievittämään pitkäkestoisesti ADHD:n aiheuttamia ja muita siihen liittyviä oireita, ja parantamaan auditiivista tarkkaavuussuoriutumista reaktioaikatehtävässä.

Menetelmät. Tutkimuksessa on hyödynnetty EEG-mittauksia (osatutkimukset I–II), behavioraalisia reaktioaikamittauksia (CPT; osatutkimus III) ja kliinisen tutkimuksen arviointimenetelmiä (itseraportoidut oirekyselyt, riippumaton ulkoinen arviointi; osatutkimus IV). Kolmen ensimmäisen osatutkimuksen koeasetelma oli rakenteeltaan samanlainen. Niissä mittaukset toteutettiin neljässä peräkkäisessä koetilanteessa: 1) ennen hypnoosia (perustilanne), 2) hypnoosi-induktion jälkeen (neutraalin hypnoosin tilanne), 3) hypnoosissa annettujen, koetilannekohtaisten suggestioiden jälkeen (hypnoosisuggestiotilanne) ja 4) hypnoosin ja suggestioiden purkamisen jälkeen (jälkitilanne). Ensimmäisessä ja toisessa osatutkimuksessa oli yhteinen yhdeksän hypnoosiherkän osallistujan EEG-mittaus. Ensimmäisessä osatutkimuksessa mitattiin EEG:n tehotiheydet kymmeneltä elektrodilta keskilinjan molemmin puolin. Toisessa osatutkimuksessa mitattiin passiivista ”oddball”-paradigmaa käyttäen aivojen tapahtumasidonnaisen jännitevasteen (ERP, event-related potential) esitietoinen auditiivinen MMN-komponentti kolmelta frontaalielektrodilta, joissa MMN:n amplitudi on tyypillisesti voimakkain. Hypnoosisuggestiotilanteen suggestioilla pyrittiin muuttamaan osallistujan kuulohavaintoa siten, että kaksi taustalla kuuluvaa siniääntä (vakioääni 500 Hz, poikkeava ääni 520 Hz) kuulostavat hänestä saman korkuisilta. Kolmannessa osatutkimuksessa ADHD-aikuisten ja kontrolliryhmän osallistujien reaktioaikoja mitattiin kolmen minuutin auditiivisessa CPT-testissä ja hypnoosisuggestiotilanteen suggestioilla pyrittiin parantamaan osallistujien suoriutumisnopeutta. Neljännessä osatutkimuksessa, joka on kontrolloitu seurantatutkimus hypnoterapian soveltamisesta ADHD-aikuisten kuntoutukseen, analysoitiin kuuden kuukauden seuranta-aineisto kymmenen tapaamiskerran yksilöllisestä hypnoterapiasta ja kognitiivis-behavioraalisesta terapiasta (CBT). Osatutkimusten tilastollisissa analyyseissä on käytetty muun muassa toistettujen mittausten varianssianalyysiä ja t-testiä.

Tulokset. Ensimmäisessä osatutkimuksessa havaittiin, ettei thetan tai muiden EEG:n taajuuskaistojen tehotiheyttä voida käyttää erottamaan hypnoosiherkkien osallistujien hypnoositilaa normaalista valvetilasta. Toisessa osatutkimuksessa ei löydetty tukea sille, että hypnoositila tai hypnoosissa annetut kuulohavaintoa muuttamaan pyrkivät suggestiot vaikuttaisivat MMN:n amplitudiin hypnoosiherkillä osallistujilla. Kolmas osatutkimus osoitti, että hypnoosissa annetut suggestiot nopeuttivat reaktioaikoja sekä ADHD-henkilöillä että terveillä kontrolliryhmän osallistujilla. Neljännessä osatutkimuksessa havaittiin, että kuuden kuukauden seurannassa kuntoutushyödyt säilyivät sekä hypnoterapia- että CBT-ryhmissä oiremittareilla itsearvioituna, kuitenkin hypnoterapiaryhmässä CBT-ryhmää paremmin. Ryhmät erosivat seurannassa toisistaan hypnoterapiaryhmän eduksi yleisessä psyykkisessä hyvinvoinnissa, ahdistuneisuudessa ja masentuneisuudessa, ja erosivat tilastollisesti viitteellisesti toisistaan toisella kahdesta tarkkaavuushäiriön oiremittarista.

Johtopäätökset. Väitöskirjan johtopäätökset ovat: 1) theta-kaistan tehotiheyttä ei voida käyttää erottelemaan hypnoosia ja valvetilaa toisistaan hypnoosiherkillä henkilöillä, kuten aiemmassa kirjallisuudessa on ehdotettu, 2) hypnoosisuggestioilla voidaan nopeuttaa auditiivista tarkkaavuussuoritusta reaktioaikatehtävässä, mutta niillä ei todennäköisesti pystytä vaikuttamaan esitietoisen MMN-vasteen heijastamiin aivomekanismeihin, 3) hypnoosi ja hypnoterapia ovat käyttökelpoisia hoitomenetelmiä myös aikuisilla, joilla on ADHD. Hypnoosissa annetut suggestiot nopeuttivat heidän suoriutumistaan auditiivisessa reaktioaikatehtävässä. ADHD-kuntoutusten kuuden kuukauden seurannassa hypnoterapian hyötyjen havaittiin säilyneen jopa paremmin kuin CBT:ssä, joka on kirjallisuudessa eniten tutkittu ja parhaana pidetty psykologinen kuntoutusmenetelmä ADHD-aikuisilla.

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Kirkkonummi 25.8.2021

To my mom and dad, I miss you

CONTENTS

List of original publications

The present thesis is based on the following publications:

I Hiltunen, S., Karevaara, M., Virta, M., Makkonen, T., Kallio, S., & Paavilainen, P. (2021). No evidence for the theta power as a marker of hypnotic state in highly hypnotizable subjects. *Heliyon*, 7(4), e06871.

II Hiltunen, S., Virta, M., Kallio, S., & Paavilainen, P. (2019). The effects of hypnosis and hypnotic suggestions on the mismatch negativity in highly hypnotizable subjects. *International Journal of Clinical and Experimental Hypnosis,* 67(2), 192–216.

III Virta, M., Hiltunen, S., Mattsson, M., & Kallio, S. (2015). The impact of hypnotic suggestions on reaction times in continuous performance test in adults with ADHD and healthy controls. *PLOS One,* 10(5), e0126497.

IV Hiltunen, S., Virta, M., Salakari, A., Antila, M., Chydenius, E., Kaski, M., Vataja, R., Iivanainen, M., & Partinen, M. (2014). Better long-term outcome for hypnotherapy than for CBT in adults with ADHD: results of a six-month follow-up. *Contemporary Hypnosis and Integrative Therapy* 30(3), 118–134.

The publications are referred to in the text by their Roman numerals.

ABBREVIATIONS

ADHD	attention deficit hyperactivity disorder
ANOVA	analysis of variance
ANT	attention network test
APA	American psychological association
BADDS	Brown attention deficit disorder scale, adult version
BDI-II	Beck depression inventory, second edition
CBT	cognitive behavioral therapy
CGI	clinical global impressions
CMS	common mode sense
CPT	continuous performance test
DSM-IV	diagnostic and statistical manual of mental disorders, version IV
EEG	electroencephalography
ERP	event-related potential
FEF	frontal eye fields
fMRI	functional magnetic resonance imaging
HEOG	horizontal electrooculogram
HGSHS:A	Harvard group scale of hypnotic susceptibility, form A
HT	hypnotherapy
HY	neutral-hypnosis condition
ICA	independent component analysis
IFG	inferior frontal gyrus
IFJ	inferior frontal junction
ISI	interstimulus interval
MMN	mismatch negativity
PCA	principal component analysis
PoH	post-hypnosis condition
PrH	pre-hypnosis condition
rmANOVA	repeated-measures analysis of variance
RT	reaction time
RTV	reaction time variability
SU	hypnotic-suggestion condition
SHSS:C	Stanford hypnotic suggestibility scale, form C
SPL	superior parietal lobule
TPJ	temporo-parietal junction
VEOG	vertical electrooculogram
WAIS-IV	Wechsler adult intelligence scale, version IV

1 Introduction

The present thesis combines three broad research areas: hypnosis, attention and attention deficit hyperactivity disorder (ADHD). Hypnosis is the converging factor within those areas and the effects of hypnosis and hypnotic suggestions on attention and ADHD have been investigated.

The phenomenon of hypnosis has existed long before recorded history (Kluft, 2015). Historical roots of western hypnosis are in Mesmerism, which was based on the "animal magnetism" theories of Frantz Anton Mesmer (1734-1815). Mesmer's theories were later rejected, but the curious phenomena demonstrated by him were real and needed explanation (Hammond, 2013). The honor of the naming of hypnosis, based on the Greek word *hypnos* for sleep, has been given to Scottish surgeon James Braid (Elkins, Barabasz, Council, & Spiegel, 2015). In the early 19th century, some methods of Mesmerism were adapted by Dr. Braid into his medical practice. Initially, he thought that hypnosis was similar to sleep, but later realized that his hypnotized patients were not asleep. Hypnosis is commonly referred to as a method where one person is guided by another to respond to suggestions for changes in subjective experience and alterations in perception, sensation, emotion, thought or behavior (Green, Barabasz, Barrett, & Montgomery, 2005). In hypnotic induction, a procedure used to induce hypnosis, the strong focusing or narrowing of attention is typically used together with relaxation. Spiegel (2003) has suggested that hypnosis is related to alertness and attention, but is not a direct consequence of them. Despite the long history of hypnosis, its influences on brain mechanisms are still mainly unknown (Terhune, Cleeremans, Raz, & Lynn, 2017). Some studies have shown that even preconscious and automatic processes of the brain can be influenced by hypnosis and suggestions (e.g., Kallio & Koivisto, 2013; Koivisto, Kirjanen, Revonsuo, & Kallio, 2013; Zahedi, Stuermer, Hatami, Rostami, & Sommer, 2017). Consequently, hypnosis may have an unexplored potential over other methods, for instance, traditional cognitive psychology methods for investigating information processing in the brain.

The concept of attention, the function of which centrally influences human performance, extends back to the beginning of experimental psychology (James, 1890). Attention is a cognitive process that influences all other cognitive processes (e.g., Posner & Petersen, 1990). By means of attention, we can selectively concentrate on one aspect of the environment while ignoring other parts of it. Problems in attention can cause negative life outcomes. For example, in adults with ADHD there is dysfunction in both attention and executive functions, causing longstanding problems in everyday life (Goodman, 2007).

The frontostriatal network, cerebellum and dopaminergic system of the brain are related to ADHD symptoms (Barkley, 2006; Cherkasova & Hechtman, 2009). The frontostriatal network and dopaminergic system are also closely involved with hypnosis (Nash & Barnier, 2008). The capability to ignore irrelevant information and to focus attention, which is typical with hypnosis (Crawford, 1994), is normally problematic for adults with ADHD. Since hypnosis and ADHD both influence the same frontal brain areas and attentional mechanisms, it is interesting to combine these three phenomena – hypnosis, attention and ADHD – into the same thesis. The present thesis contains four studies that progressively build toward a deeper understanding of hypnosis and its capability to influence human attentional functions in both healthy persons as well as in therapeutic treatments in adults with ADHD.

2 Review of the literature

2.1 Attention

2.1.1 What is attention?

Over a century ago, William James (1890, p. 403–404) famously defined attention in the following way: "Everyone knows what attention is. It is the taking possession of the mind, in clear and vivid form, of one out of what seem several simultaneously objects or trains of thought. Focalization, concentration, of consciousness are its essence. Its withdrawal from some things in order to deal effectively with others". Since then, and especially during recent decades, attention research has been one of the fastest-growing areas within cognitive psychology and cognitive neuroscience (Posner & Rothbart, 2007).

Two main types of attention have been defined: *voluntary*, goal-directed (top-down) and *involuntary*, stimulus-driven (bottom-up) attention (Corbetta & Shulman, 2002). Thus, in everyday life, attention is controlled by both cognitive (top-down) factors, such as knowledge, expectation and current goals, and also bottom-up factors that reflect sensory stimulation. As an example of the latter, for instance, an unexpected loud tone in the environment may catch one's attention involuntarily and automatically, and interrupt currently ongoing tasks.

According to Knudsen (2007), the four fundamental processes for attention are working memory, top-down sensitivity control, competitive selection, and automatic bottom-up filtering for salient stimuli. Each of these processes makes a distinct and essential contribution to attention. Voluntary control of attention involves the first three processes, whereas automatic bottom-up filtering for salient stimuli is involuntary. Attention is proposed to operate through a kind of filter or bias deployed to enhance or suppress different perceptual modalities, spatial locations, stimulus features or object representations (Gratton, Cooper, Fabiani, Carter, & Karayanidis, 2018). Thus, these biases serve to extract information that is relevant to the current task goals in voluntary control.

In the theoretical model of Posner & Petersen (1990), the attention system of the human brain includes different, but interrelated systems/functions, namely *orienting*, *detecting*, and *alerting*. *Orienting* means the aligning of attention with a source of any sensory modality input or an internal semantic structure stored in memory (Posner, 1980). Orienting has been closely tied to the orienting reflex (Sokolov, 1963), the operation of which is a complex of autonomic, motor and subjective reactions to accentuate the processing of new and significant stimuli (Sokolov, Nezlina, Polyanskii, & Evtikhin, 2002). *Detecting* means to be aware or conscious of a target stimulus (Posner, 1980), which also produces widespread interference with most other cognitive operations (Posner & Petersen, 1990). Often, in addition to detecting the presence of the target, the target must be identified in order to discriminate it from a complex background (Posner, Snyder, & Davidson, 1980). As a consequence of the detection, a wide range of arbitrary responses can be produced (Posner & Petersen, 1990), for instance, reporting the presence of the target. *Alerting*, in turn, is a process of achieving and maintaining a state of high sensitivity to incoming stimuli (e.g., Posner & Petersen, 1990; Raz, 2004). The process is important for *sustained attention* (Oken, Salinsky, & Elsas, 2006), which is typically needed in operations where a relevant event occurs at a relatively slow rate over a prolonged period, for instance, in various quality control or surveillance tasks.

Selective attention refers to a differential processing of simultaneous sources of information, where the sources can be internal (memory and knowledge) or external (objects and events in one's environment) (Johnston & Dark, 1986). Consequently, attention can voluntarily be directed to, for instance, any nonfixated locations or objects in the visual space (Posner, 1980). This top-down control of visual selection has often been metaphorically described as a form of a spotlight (Broadbent, 1982; Posner et al. 1980), or a zoom lens (Eriksen & Yeh, 1985). Attention can also be directed to, for instance, two objects at the same time, a phenomenon known as *divided attention* (McMains & Somers, 2004). Attention can also be allocated *overtly* (e.g., by directing one's eyes toward a location) or *covertly* (by means of internal attentional mechanisms, without any external signs of the object of allocation) (Carrasco, 2011). Since attention can be moved to a potential source of signals before any sensory input has occurred, orienting can occur without the detection (Posner, 1980). Thus, the orienting and the detecting are two quite distinct internal operations of attention. Also, the concept of *executive attention* has sometimes been used. It involves the detection and resolution of the conflict in cognitive operations, as well as the production of appropriate behavioral responses (Mahoney, Verghese, Goldin, Lipton, & Holtzer, 2010).

Attention in the auditory modality can be conceptualized with similar processes and terms as in visual attention, although the processes may also vary depending on the sensory modality and the current tasks (Alain, Arnott, & Dyson, 2013). According to Alain et al. (2013), the processes that are engaged during everyday listening situations are sustained attention, selective attention, and divided attention. Each process plays an important role in demanding listening situations that are often illustrated, for instance, using Cherry's (1953) cocktail party example. The example demonstrates how one can selectively listen to a particular conversation at a party and apparently be oblivious to other ongoing conversations, but remain sensitive to potentially important information (e.g., for his/her own name) in the other conversations (Johnston & Dark, 1986). The auditory environment need not necessarily be actively monitored in order to notice occasional or peculiar changes in sounds. Infrequent changes can be automatically detected and a bottom-up, involuntary type of attention shift triggered by them (Alain et al., 2013; Näätänen, Gaillard, & Mäntysalo, 1978). Correspondingly, an occasional salient visual stimulus can easily be noticed even in the peripheral visual field.

Cognitive control, which is closely related to concepts of attentional control and executive functions, encompasses processes involved in generating and maintaining appropriate task goals and suppressing the processing of non-relevant goals (Gratton et al., 2018). By means of cognitive control mechanisms, current goals can modify attentional biases, for instance, in order to improve task performance. Attentional biases then enhance cortical sensory and sensory-associational information processing including the filtering of noise and distractors (Sarter, Givens, & Bruno, 2001). The biases also interact over modalities: when attending to something in one modality, for example an object in a visual scene, reduced responsiveness has been observed in peripheral processing organs of another modality, such as the cochlea in the auditory system (Fritz, Elhilali, David, & Shamma, 2007).

Concepts of *controlled* and *automatic* information processing are also important. Schneider and Siffrin (1977) have defined automatic processing as an activation of a learned sequence of elements in long-term memory that is initiated by appropriate inputs and then proceeds automatically and fastly without volitional control by the subject, without stressing the capacity limitations of the system, and without necessarily demanding attention. Controlled processing, in turn, is based on a temporary activation of a sequence of elements that can be set up quickly and easily but requires attention, is capacity-limited (usually serial in nature), slow and volitionally controlled by the subject.

2.1.2 Brain mechanisms of attention

The human frontoparietal cortex has been shown to be closely involved in attentional control (Scolari, Seidl-Rathkopf, & Kastner, 2015). In a functional network division made by Petersen and Posner (2012, see also 1990), attention includes *an alerting network, an orienting network* and *an executive network*. The alerting network, which includes the brain stem and cerebral cortex arousal systems, is related to sustained vigilance. The orienting network focuses on, among other regions, especially the parietal cortex whereas the executive network, in turn, includes the midline frontal/anterior cingulate cortex (Petersen & Posner, 2012).

The aforementioned categories are not the only way to divide attention networks anatomically and functionally. About two decades ago, an influential review by

Corbetta and Shulman (2002) introduced the concept of two attention systems in the human brain. These two segregated networks were proposed to serve top-down controlled and bottom-up triggered orienting of attention. However, it should be noted that the naming of the networks has varied in the literature. Corbetta and Shulman (2002) originally used the terms *dorsal attention network* and *ventral frontoparietal network*, but the terms *dorsal and ventral attention systems/networks* (e.g., Vossel, Geng, & Fink, 2014) and *dorsal and ventral frontoparietal networks* (Shulman et al., 2009; Shulman et al., 2010) have also commonly been used. Additionally, these two attention networks are in the literature at times grouped into a single larger "executive control" network (Gratton, Sun, & Petersen, 2018). To avoid confusion in the nomenclature surrounding the networks, the terms dorsal frontoparietal network and ventral frontoparietal network are henceforth used in the present thesis.

The dorsal frontoparietal network participates in preparing and applying voluntary, goal-directed (top-down) selection for stimuli and responses, and it includes parts of the superior frontal cortex and the intraparietal cortex (Corbetta & Shulman, 2002). The superior parietal lobule (SPL) is an important area of top-down attention in the parietal cortex (Shomstein, Lee, & Behrmann, 2010). *The ventral frontoparietal network*, in turn, is specialized for the involuntary detection of behaviorally relevant stimuli (Corbetta & Shulman, 2002). This right-hemisphere dominant network includes brain areas in the inferior frontal cortex and the temporoparietal cortex, enabling interruption of the dorsal frontoparietal network and re-direction of attention to salient events. The important area for bottom-up attention in the temporoparietal cortex includes the temporo-parietal junction (TPJ) in particular (Shomstein et al., 2010). Although the ventral frontoparietal network was originally proposed to be lateralized to the right hemisphere (Corbetta & Shulman, 2002), bilateral activation of the TPJ has been reported (Vossel et al., 2014). In the frontal cortex, the frontal eye fields (FEF), inferior frontal junction (IFJ), and inferior frontal gyrus (IFG) are involved in both top-down and bottom-up attentional control (Shomstein, 2012). The reorienting response to, for instance, potentially advantageous or threatening stimuli involves coordinated actions of these two attention networks (Corbetta, Patel, & Shulman, 2008). Controlling eye movements, which is important for overt visual attention, involves the FEF, its supplementary area and subcortical areas such as the pulvinar in the thalamus and the superior colliculus (Alvarez, 2013).

Flexible attentional control, depending on the current task demands, can only be implemented by dynamic interactions of both ventral and dorsal frontoparietal networks (Vossel et al., 2014). This interaction has been proposed to be accomplished via the frontal lobe, especially in the IFJ and IFG areas (Shomstein, 2012). Many distinct brain areas are involved in attention since functional magnetic resonance imaging (fMRI) has shown the topography of frontoparietal cortex networks involving 18 independent subregions in individual subjects (Scolari et al., 2015).

In most attention control tasks where attention is directed externally, the activation in the frontoparietal network has been observed to increase with task demands (Unsworth & Robison, 2017). In these tasks, the activation of the *default mode network*, which is typically active during remembering, envisioning the future and mind wandering (Buckner & DiNicola, 2019), has been observed to decrease (Unsworth & Robison, 2017). Thus, in demanding external attention tasks, the frontoparietal network suppresses the default mode network in order to prevent potentially distracting thoughts to interfere with the task goals (Spreng et al., 2014). When the external task requires the retrieval of information from memory, the two networks work together (Konishi, McLaren, Engen, & Smallwood, 2015). The competition between the frontoparietal network and the default mode network has been associated with lapses of attention, inconsistency in attention control, and subjective reports of mind-wandering (Unsworth & Robison, 2017).

Performance requiring sustained attention, for instance knowledge-driven detection and selection of target stimuli, has been shown to be mediated by the basal forebrain cholinergic system (Sarter et al., 2001; Villano et al., 2017). Locus coeruleus and norepinephrine system provide inputs to the ventral frontoparietal network for reorienting (Corbetta et al., 2008). Variability in locus coeruleus and norepinephrine system functioning has been observed to account for individual differences in working memory capacity and attentional control (Unsworth & Robison, 2017). Executive attention has been associated with activity in the anterior cingulate cortex, medial frontal cortex, and lateral prefrontal cortex, and with dopamine as a neurotransmitter (Mahoney et al., 2010; Posner, Sheese, Odludas, & Tang, 2006; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Bush, Luu, & Posner, 2000; MacDonald, Cohen, Stenger, & Carter, 2000). Right anterior insula/medial frontal operculum has been shown to have a role in behavioral tasks in coordinating and evaluating task performance with varying perceptual and response demands (Eckert et al., 2009), and the insula has also been shown to participate in allocating auditory attention and tuning in to novel auditory stimuli (Bamiou, Musiek, & Luxon, 2003).

However, there are modality-specific differences in attentional control (see, e.g., O'Leary et al., 1997; Hill & Miller, 2010). In the auditory modality, both top-down controlled attention shifts (e.g., with a cued task) and bottom-up type of attention triggering (e.g., by louder tones in the environment) have been associated with enhanced activity in the superior temporal gyrus and sulcus, TPJ, SPL, inferior and middle frontal gyri, FEF, supplementary motor area, and anterior cingulate gyrus (Alho, Salmi, Koistinen, Salonen, & Rinne, 2015). Thus, in audition, unlike in vision, top-down controlled and bottom-up triggered attention activate largely the same cortical networks.

2.1.3 Specific brain mechanisms in involuntary auditory attention: Mismatch negativity

The most common method used in investigating brain mechanisms related to attention is electroencephalography (EEG). EEG, having excellent temporal resolution, allows the measuring of event-related potentials (ERPs), tiny electrical responses time-locked to specific sensory stimuli. A widely-studied sensory ERP component, related to the triggering of involuntary bottom-up auditory attention, is the *mismatch negativity* (MMN) (Näätänen, Paavilainen, Rinne, & Alho, 2007). MMN is a fronto-central, relatively automatic and attention-independent negative deflection to an auditory stimulus change. It usually peaks 100–250 ms after the onset of occasional "deviant" stimuli, presented among physically similar "standard" stimuli (see, e.g., Sussman, 2007; Näätänen, Paavilainen, Rinne, & Alho, 2007). MMN is elicited even though the subject's attention is directed away from the auditory stimuli, for instance, in video watching. The generation of MMN is largely independent of attention, but top-down effects of, for instance, task demands, highly-focused attention or even concurrent motor actions can modulate the strength of the response (e.g., Woldorff, Hillyard, Gallen, Hampson & Bloom, 1998; Sussman, Winkler, Huotilainen, Ritter, & Näätänen, 2002; Tiainen, Tiippana, Paavilainen, Vainio, & Vainio, 2017; Sussman, 2007). MMN amplitude has also been observed to decrease in mental fatigue (Yang, Xiao, Liu, Wu, & Miao, 2013), as well as during sleepiness and drowsiness (Paavilainen et al., 1987; Sallinen & Lyytinen, 1997).

Näätänen et al. (1978) introduced his original sensory-memory trace interpretation of MMN, according to which the MMN is elicited by sensory input deviating from the contents of a memory trace (a kind of "template" storing the physical features of the frequent standard stimulus). More recently, the MMN has been explained in terms of the regularity-violation account (Winkler, 2007). According to this account, the human auditory system constantly creates representations of the regularities embedded in the auditory environment. Temporally aligned predictions are compared with incoming stimuli, and if the predictions are violated, the MMN is elicited, reflecting the updating of the regularity representations.

Sources of MMN have been localized in the temporal lobe on the auditory cortices and in the frontal cortices (Alho, 1995). The temporal areas are suggested to be involved in the regularity extraction and change-detection processes, whereas the frontal areas are associated with attention-switch mechanisms (Rinne, Alho, Ilmoniemi, Virtanen, & Näätänen, 2000): The MMN signal is transmitted from the auditory cortices to the frontal lobes, which may elicit an involuntary attention switch to the stimulus change (Escera, Yago, & Alho, 2001; Näätänen et al., 2007). Thus, the MMN mechanism automatically alerts regarding potentially important changes in the unattended auditory environment and directs attentional resources for their further processing. The involuntary bottom-up attention shifts are manifested in the P3a component, often following the MMN, especially to salient deviants (see, e.g., Alho, Winkler, Escera, Huotilainen, Virtanen, Jääskeläinen, Pekkonen & Ilmoniemi, 1998; for a review, see Escera & Corral, 2007).

2.1.4 Measuring attention

At the behavioral level, attentional functionality is closely related to executive functions and working memory (see, e.g., Knudsen, 2007), and attentional performance can be measured in multiple ways. Many tests measuring attention are multifactorial, and they typically also measure performance in other cognitive or executive functions. In clinical use, the most commonly used tests are digit span from the Wechsler Adult Intelligence Scale–IV (WAIS-IV; Wechsler, 2008) and Trail Making (see, e.g., Lezak, Howieson, Bigler, & Tranel, 2012). For research use, specific theory-based tests measuring attentional performance have also been developed. An example of such tests is the Attention Network Test (ANT) which examines the efficiency of the afore-mentioned three brain networks underlying attention: alerting, orienting and executive attention (Fan, McCandliss, Sommer, Raz, & Posner, 2002).

Continuous Performance Tests (CPTs), the first version of them introduced by Rosvold, Mirsky, Sarason, Bransome, and Beck (1956), are commonly used both in clinical practice and in research on sustained attention. CPTs are considered to be sensitive and reliable measures of attention and attentional dysfunction (Albrecht, Uebel-von Sandersleben, Wiedmann, & Rothenberger, 2015; Bálint et al., 2009; Riccio, Reynolds, Lowe, & Moore, 2002). In the different versions of CPTs, the participants are usually required to detect a target stimulus among nontargets or react to all stimuli except for the target. The task usually takes 10–30 minutes (Huang-Pollock, Karalunas, Tam, & Moore, 2012) and the stimuli are most usually presented visually.

2.2 Attention deficits

2.2.1 Attention deficit hyperactivity disorder

Attention deficits are involved in many disorders, such as in cerebrovascular diseases (e.g., Alonso-Prieto et al. 2002; Zhang, Wang, Zhang, & Zhao, 2018), autism (New et al., 2010), schizophrenia (Carter et al., 2010) and depression (Rock, Roiser, Riedel, & Blackwell, 2014). Deficits may also be related to situational factors, such as sleep deprivation (Goel, Rao, Durmer, & Dinges, 2009). A specific disorder with clinically remarkable levels of attention deficits, as already indicated by its name, is *attention deficit hyperactivity disorder* (ADHD). ADHD is a developmental neuropsychiatric disorder, which is characterized by deficits in attention and executive functions and/or symptoms of hyperactivity and impulsivity (American Psychiatric Association, 2013). Some adults with ADHD have the symptoms of hyperactivity, but often those are limited to feelings of restlessness. Emotional dysregulation, if not considered as one of the core symptoms in ADHD, is, at least, a comorbid symptom (Adler & Silverstein, 2018; Mitchell, Robertson, Anastopolous, Nelson-Gray, & Kollins, 2012; Retz, Stieglitz, Corbisiero, Retz-Junginger, & Rosler, 2012). ADHD emerges in childhood and often continues into adulthood, where its prevalence has been estimated to be 2.5–3.4% (Fayyad et al., 2007; Simon, Czobor, Balint, Meszaros, & Bitter, 2009).

According to Brown's (2005) model of ADHD, the disorder typically manifests as deficits in organizing, prioritizing, and activating oneself to work; focusing, sustaining, and shifting attention to tasks; sustaining effort, regulating alertness and processing speed; modulating emotions and managing frustration; utilizing working memory and accessing memory recall, and/or monitoring and self-regulating actions. The aforementioned deficits cause difficulties with school, work, family interactions, and social activities in adulthood (Goodman, 2007). In addition, psychiatric comorbidities such as anxiety, depression and personality disorders are common (Biederman, 2004; Jacob et al., 2007; McGough et al., 2005; Sobanski et al., 2007; Sprafkin, Gadow, Weiss, Schneider, & Nolan, 2007), and ADHD typically doubles the risk to be injured in accidents (Amiri, Sadeghi-Bazargani, Nazari, Ranjbar, & Abdi, 2017).

2.2.2 Neurobiology and neurophysiology of ADHD

In adults with ADHD, alterations have been found both in the structure and functioning in multiple neuronal systems and networks (Cao, Shu, Cao, Wang, & He, 2014; Cortese, 2012; Cortese et al., 2012; Rubia, 2018). In particular, impairments in several right- and left-hemispheric dorsal, ventral and medial fronto-cingulo-striato-thalamic and fronto-parieto-cerebellar networks that mediate cognitive control, attention, timing and working memory have been found (Rubia, 2018). Also, alterations in white matter structure (Onnink et al., 2015) and a decrease in total cerebral and cerebellar volume have been observed (Cortese et al., 2012). The dysfunctional areas include the anterior cingulate cortex, frontostriatal circuitry, cerebellum, temporoparietal lobes, basal ganglia, thalamus, limbic areas, hippocampus and corpus callosum (for a review see, e.g., Cortese, 2012; Cortese et al., 2012; Durston, van Belle, & de Zeeuw, 2011; Rubia, 2018). Subcortical structures and their functional pathways may also be involved (De La Fuente, Xia, Branch, & Li, 2013).

There is evidence of alterations in functional connectivity (Mostert et al., 2016; Posner, Park, & Wang, 2014; Alexander & Farrelly, 2018). For instance, ADHD adults have displayed hyperconnectivity between the two attention-related frontoparietal networks and within the default-mode and the ventral frontoparietal attention networks (Sidlauskaite, Sonuga-Barke, Roeyers, & Wiersema, 2016). In addition, the salience network was found to be hypoconnected to the dorsal frontoparietal attention network (Sidlauskaite et al., 2016). Studies have found alterations in the activity of attention networks (Cao et al., 2014; Elton, Alcauter, & Gao, 2014; McCarthy et al., 2013), the default mode network (Cao et al., 2014; Elton et al., 2014; McCarthy et al., 2013), salience network (Elton et al., 2014), sensorimotor systems (Cao et al., 2014), affective network (McCarthy et al., 2013) and executive control network (Elton et al., 2014). An abnormal interrelationship between hypo-engaged (task-positive) frontoparietal attentional networks and a poorly "switched off" hyper-engaged (task-negative) default mode network has been proposed (Rubia, 2018). Altered neural organization especially in frontal areas has been suggested to result from the need for continually high levels of cortical activation to maintain sustained attention (Loo et al., 2009).

Neurophysiological features of ADHD include less pronounced responses and longer latencies in certain ERP components, particularly in P300, when compared to healthy controls (Cortese, 2012). A recent CPT study in adults with ADHD, also co-measuring ERPs, observed that compared to controls, adults with ADHD had a reduced N1 amplitude to target stimuli, and reduced N2 and P3 amplitudes to both standard and target stimuli, highlighting deficits in early sensory processing, stimulus categorization, and in allocating attentional resources, respectively (Kaur, Singh, Arun, Kaur, & Bajaj, 2019). A meta-analysis of MMN studies with ADHD-diagnosed children has reported reduced MMN amplitudes when compared to controls (Cheng, Chan, Hsieh, & Chen, 2016). However, moderate group differences between ADHD adults and controls have been observed more in the later, more cognitive ERP components (e.g., P300) than in the early, sensory components (e.g., MMN) (Kaiser et al., 2020). In addition, an increased theta and decreased beta power (i.e., elevated theta/beta power ratio) have been observed in ADHD participants when compared to controls (Cortese, 2012). However, in ADHD adults, the theta/beta ratio did not successfully classify their ADHD status (Kiiski et al., 2019).

2.2.3 Attention tasks and ADHD

CPT is a test for evaluating sustained attentional performance. Performance in the CPT at the behavioral level is often measured by reaction times (RTs) to targets (indexing some general processing speed), errors of omission (e.g., no response to targets, often regarded as manifestations of inattention), and errors of commission (false alarms to non-targets, often regarded as indicators of impulsive responses) (Albrecht et al., 2015). Adults with ADHD make more omission and commission errors in CPT than controls (Advokat, Martino, Hill, & Gouvier, 2007; Balint et al., 2009; Epstein, Conners, Sitarenios, & Erhardt, 1998; Gualtieri & Johnson, 2006; Hervey, Epstein, & Curry, 2004; Raz, Bar-Haim, Sadeh, & Dan, 2014). There are usually no or only negligible differences in RTs (Balint et al., 2009; Hervey et al., 2004; Raz et al., 2014). However, the results are equivocal and controversial with observations also of both slower (Advokat et al., 2007; Gualtieri & Johnson, 2006) and marginally faster RTs (Epstein et al., 1998) in ADHD adults than in controls.

In the literature, *reaction time variability* (RTV) metrics have also commonly been used with ADHD patients. The RTV means intra-individual variability in RTs on computerized tasks (Tamm et al., 2012). A meta-analytic review of 319 studies (Kofler et al., 2013) concluded that children and adults with ADHD exhibit increased RTV relative to non-clinical groups, but individuals with ADHD did not evidence slower processing speed, estimated as mean RT, after accounting for RTV. Comparison with clinical control groups revealed that increased RTV is not specific to ADHD, but it is a stable feature of other clinical disorders also observed across diverse tasks and methods.

2.2.4 ADHD treatments

The management of ADHD in adulthood is based on pharmacological and psychological treatments (see, e.g., meta-review of De Crescenzo, Cortese, Adamo, & Janiri, 2017). Both pharmacological (Bitter, Angyalosi, & Czobor, 2012; De Crescenzo et al., 2017) as well as psychological treatments have been found efficient in the management of ADHD (Fullen, Jones, Emerson, & Adamou, 2020). As a result of life-long experiences of failure and underachievement, adults with ADHD have developed maladaptive negative cognitions and beliefs that decrease motivation and increase avoidance behavior and mood disturbance (Knouse & Safren, 2010; Safren, 2006; Safren, Sprich, Chulvick, & Otto, 2004). This often results in impaired self-esteem (Newark & Stieglitz, 2010). It is obvious that such cognitive distortions cannot be managed with medication alone (Mongia & Hechtman, 2012).

In clinical research, the concepts of top-down and bottom-up approaches have been used. Top-down approach treatments can be conceptualized as employing therapies (e.g., cognitive behavioral therapy, CBT) to enhance cortical influences on subcortical or limbic circuits, to undo negative learning or distorted schemas and to increase modulating effects (Fawcett, 2002). The bottom-up approach, in turn, involves the use of medication for the purpose of modulating harmful traits or states, and in such a way, "normalizing" the function of lower limbic structures. According to Rostain and

Ramsay (2006), pharmacotherapy is a bottom-up treatment for the core symptoms of ADHD, and CBT provides a top-down psychosocial approach for addressing functional problems, modifying negative thought patterns and developing new coping strategies.

Behavioral, cognitive and emotional strategies can be applied with CBT (Mongia & Hechtman, 2012; Solanto, Surman, & Alvir, 2018). Behavioral strategies may include, among others, the use of a planner for scheduling and prioritizing tasks, methods for organizing workspace, practicing self-reinforcement upon completion of adverse and difficult tasks, breaking down complex tasks to more manageable ones, visualization of the long-term reward of a present behavior or modifying the physical environment to reduce distraction and increase efficiency. Cognitive strategies may include creating "rules" for daily scheduling, prioritizing, and organizing as well as developing adaptive cognitions to facilitate task initiation, completion and planning, and addressing comorbidities of anxiety, depression and/or demoralization. Emotional strategies, in turn, may aim at improving motivation, emotional regulation and self-esteem, as well as the management of relationships, stress and anger.

In the CBT treatments for ADHD adults, group, individual and combined group and individual interventions have been applied (Fullen et al., 2020). Many recent reviews have evidenced the efficacy of CBT in treating ADHD in adults (e.g., Mongia & Hechtman, 2012; Fullen et al., 2020; Nimmo-Smith et al., 2020; Lopez-Pinar, Martinez-Sanchis, Carbonell-Vaya, Sanchez-Meca, & Fenollar-Cortes 2020; Jensen, Amdisen, Jorgensen, & Arnfred, 2016). A recent systematic review of the psychological treatments in ADHD adults by Fullen et al. (2020) summarized that the strongest empirical support was derived from CBT interventions. They found CBT to be an effective intervention based on various primary (inattention, hyperactivity/impulsivity) and secondary (psychosocial) outcome measures. A Cochrane review by Lopez et al. (2018), however, concluded two years earlier that the evidence for CBT in treating ADHD adults in the short term was still of low-quality, although the reductions in the core symptoms of ADHD were fairly consistent across the different comparisons (CBT plus pharmacotherapy versus pharmacotherapy alone and CBT versus waiting list). Lopez-Pinar and their colleagues' (2020) review, in turn, focused on treating comorbid symptoms in ADHD. They found CBT to be effective for improving quality of life and for reducing emotional dysregulation, depression, and anxiety symptoms. Again, the evidence for the reduction of depression and anxiety symptoms was considered as low-quality in the Lopez et al. (2018) review.

There exists an increasing amount of group and individual CBT intervention studies where the status of the ADHD adult participants has been followed after the end of the treatment. The duration of the follow-up periods has varied considerably between the studies. For instance, 2-month (van Emmerik-van Oortmerssen et al., 2019), 3-month (Dittner, Hodsoll, Rimes, Russell, & Chalder, 2018; Emilsson et al., 2011; Young et al., 2017; Young et al., 2015), 6-month (Cherkasova et al., 2020; Salakari et al., 2010), 9-month (Corbisiero et al., 2018; Safren et al., 2010), 12-month (Stevenson, Whitmont, Bornholt, Livesey, & Stevenson, 2002), and 18-month (Lam et al., 2019) follow-ups have been used. In most of the studies, the treatment benefits have typically remained during the follow-up, or the benefits even have increased in the shorter, three-month follow-up periods (Emilsson et al., 2011; Young et al., 2017; Young et al., 2015). However, a tendency toward an increase of symptoms during longer follow-up periods has been observed, in one group-intervention study already at three-month post-treatment (Salakari et al., 2010), but especially with follow-up periods longer than three-month post-treatment (Cherkasova et al., 2020; Corbisiero et al., 2018; Stevenson et al., 2002). However, no increase in ADHD symptoms was observed in an 18-month follow-up (52-session CBT group treatment with medication; Lam et al., 2019) where the treatment period had been remarkably longer than in the other studies (typically 10–12 sessions).

In an individual CBT intervention, Safren et al. (2010) found that responders and partial responders of 12-session CBT maintained their treatment gain during the 12-month follow-up. The participants had, however, slightly increasing scores in the self-report measures of ADHD symptoms during the follow-up. Similarly, slight increases in ADHD and emotional symptoms were observed in 10–12-session individual CBT treatment with medication at a 9-month follow-up (Corbisiero et al., 2018). During a shorter, 2-month follow-up period in 15-session individual CBT treatment for substance use disorder (primary diagnosis) and ADHD patients, the symptoms remained at about the same post-treatment level (van Emmerik-van Oortmerssen et al., 2019). CBT treatment given in an individual setting, in general, has been more effective in improving self-esteem, depression, and anxiety comorbid symptoms than group CBT (Lopez-Pinar et al., 2020).

There exists no research literature about applications of hypnotherapy for treating adults with ADHD, except for one study (Virta et al., 2010a). In the present thesis, the follow-up data from this previous study and a CBT study (Virta et al., 2010b) are compared. The hypnotherapy study was a randomized controlled study, which investigated the utility and efficacy of short-treatment hypnotherapy, specifically tailored for treating adults with ADHD (Virta et al., 2010a). Both individual interventions resulted in reduced self-reported ADHD symptoms and no difference was found in symptom reduction between CBT and hypnotherapy treatments at the end of the treatment (Virta et al., 2010a). In general, according to many reviews and meta-analyses, the strongest research evidence for the efficacy of hypnotherapy is from the treatments of inflammatory bowel diseases (Ford et al., 2014; Gholamrezaei, Ardestani, & Emami, 2006; Lee, Choi, & Choi, 2014; Peters, Muir, & Gibson, 2015; Schaefert, Klose, Moser, & Hauser, 2014). For other purposes, the effectiveness of hypnotherapy has previously been reviewed by Cowen (2016) and Kirsch, Montgomery, and Sapirstein (1995). Hypnotherapy has also been applied to anxiety (see, e.g., Golden, 2012) and depression (see, e.g., Alladin, 2012a), which are typical comorbidities of ADHD.

2.3 Hypnosis

2.3.1 What is hypnosis?

Hypnosis is a phenomenon characterized by many scientifically questionable myths (Meyerson, 2014). For instance, movies have often promoted negative, stereotypic prejudices that the use of hypnosis is dangerous and displayed the interaction between the person administering hypnosis and the hypnotized person as seductive or exploitive (Barrett, 2006). Those prejudices are, however, misleading from the perspectives of the clinical and research practice (Terhune et al., 2017; Raz, 2011). The most commonly accepted definition of hypnosis (and the definitions of its related concepts) has been provided by American Psychological Association (APA) division 30 (see Elkins, Barabasz, Council, & Spiegel, 2015, p. 382–383):

Hypnosis	"A state of consciousness involving focused attention and reduced peripheral awareness characterized by an enhanced capacity for response to suggestion."
Hypnotic induction	"A procedure designed to induce hypnosis."
Hypnotizability	"An individual's ability to experience suggested alterations in physiology, sensations, emotions, thoughts, or behavior during hypnosis."
Hypnotherapy	"The use of hypnosis in the treatment of a medical or psychological disorder or concern."

Some criticism for the current definitions has been presented. For instance, the assumption of hypnosis as a specific "state" has been seen to play too important of a role over the "non-state" or sociocognitive theories of hypnosis (Lynn, Green, et al., 2015). The long debate between the state and sociocognitive theories has centered on the question of whether hypnosis should be regarded as a distinct state of consciousness with specific neurophysiological correlates or simply as a product of expectations and social influence (see, e.g., Kallio & Revonsuo, 2003; Kihlstrom, 2005; Kirsch & Lynn, 1995). This question has nowadays been recommended to be left unsolved and the focus of research to be redirected away from contrasting those two positions (Jensen et al., 2017; Terhune et al., 2017). According to Dell (2017), the definitions above have also lost sight of the spontaneous self-activation of hypnosis. Hypnosis should rather be characterized as a motivated mode of neural functioning that enables most humans to alter, to varying degrees, their experience of body, self, actions, and world.

The hypnotic induction procedures include implicit (e.g., promoting deeper relaxation) and often also explicit suggestions to experience or “enter” hypnosis (e.g., “you enter deeper and deeper hypnosis”). Many inductions implicitly inform participants that they will experience the effects of hypnosis as just “happening” to them, which contributes to the experience of involuntariness (Lynn, Laurence, & Kirsch, 2015).

Suggestion, a concept not related to hypnosis alone, is also necessary to define. Halligan and Oakley (2014), as a starting point, referred to American psychologist Boris Sidis’ (1867–1923) first definitions of suggestion. They pointed out that for Sidis, a suggestion was a communicable idea – a form of belief – that under certain levels of suggestibility could be communicated directly or indirectly, and resulting in automatic and rapid, temporary or permanent alterations in the subject's experience or behavior. Halligan & Oakley (2014, p. 111) provided, by expanding Sidis’ view to the more traditional domain of hypnotic suggestion, the following working definition:

Suggestion	“A form or type of communicable belief capable of producing and modifying experiences, thoughts and actions. Suggestion can be (a) intentional/nonintentional, (b) verbal/nonverbal, or (c) hypnotic/nonhypnotic.”

Suggestions can be *hypnotic* or *non-hypnotic* depending on whether they are administered with or without hypnosis, that is, with or without a hypnotic induction (Halligan & Oakley, 2014). When suggestions are given in a hypnotic context, they can be administered by a person designated or perceived to be in the role of a “hypnotist” or the suggestions can be self-administered, in which case the situation is construed as “self-hypnosis” (Lynn, Laurence, et al., 2015). Behavior and sensations induced by suggestions in a hypnotic state are often thought to happen automatically and involuntarily (Kirsch & Lynn, 1997). Also, similarly to hypnotic induction, suggestions are typically worded as involuntary happenings rather than voluntary actions (e.g., Terhune et al., 2017). Suggestions may vary in terms of their generality (e.g., full-body relaxation) versus specificity (e.g., rehearse in one’s imagination a specific future event) and in their wording (e.g., permissive versus authoritative tone) (Lynn, Laurence, et al., 2015).

Posthypnotic suggestions are suggestions that are administered during hypnosis but intended to take their effects following the termination of the hypnotic experience, that is, after the formal hypnosis session has ceased (e.g., Barnier & McConkey, 1999; Halligan & Oakley, 2014). Thus, the suggestions can be (partially) separated from the hypnotic context (Terhune et al. 2017). Posthypnotic suggestions are useful, for instance, for therapeutical purposes, since further improvements due to the suggestions are intended to take effect after a treatment session.

Hypnotizability, an individual's ability to respond to the suggestions, remains quite stable over the lifespan (Piccione, Hilgard, & Zimbardo, 1989). This ability is normally distributed in the population, with approximately 10–15% being low hypnotizables, 70–80% being medium hypnotizables, and 10–15% being high hypnotizables (Woody, Barnier, & McConkey, 2005). This term (Elkins et al., 2015) is also used in the present thesis. However, the term *hypnotic suggestibility* may be the most theory-neutral descriptive term for what is being measured by hypnosis scales, namely responsiveness to direct verbal suggestions (i.e., suggestibility) following an induction (Acunzo & Terhune, 2019, September 16). Typically, a hypnotizability measure involves administering a standard induction procedure, suggesting a number of hypnotic experiences, and scoring responses according to predefined criteria (Barnier & McConkey, 2004). High hypnotizability is defined as a high score in such a measure. Barnier and McConkey (2004) have listed 13 different measurement scales of which the *Harvard Group Scale of Hypnotic Susceptibility, Form A* (HGSHS:A) and *Stanford Hypnotic Suggestibility Scale, Form C* (SHSS:C) are the most commonly used in research. The HGSHS:A, as a group assessment, is less resource-intensive and less demanding on participants than the SHSS-C, which is an individual assessment. What is also noteworthy is that hypnotic responses between individuals are heterogeneous and not hypnotizability-dependent. For instance, highly hypnotizable persons with equal hypnotizability scores have been observed to experience the same suggestions quite differently (e.g., Kallio, Koivisto, & Kaakinen, 2017).

Hypnotizability and performance in various attentional tasks have not been observed to correlate (Varga, Nemeth, & Szekely, 2011), but in at least one ANT study (Castellani, D'Alessandro, & Sebastiani, 2007), high hypnotizables exhibited a bit shorter reaction times than lows.

2.3.2 Brain mechanisms of hypnosis

Attention is a key factor in hypnosis and hypnotic processes (Karlin, 1979; Raz, 2005). Several studies have reported hypnosis-related activity changes in the prefrontal cortex and anterior cingulate cortex (Egner, Jamieson, & Gruzelier, 2005; McGeown, Mazzoni, Venneri, & Kirsch, 2009; Rainville, Hofbauer, Bushnell, Duncan, & Price, 2002). Hypnosis has been shown to change the functional connectivity of the brain (Fingelkurts, Fingelkurts, Kallio, & Revonsuo, 2007a; Hoeft et al., 2012; Jamieson & Burgess, 2014), decrease activity in the default mode network (Deeley et al., 2012; Demertzi et al., 2011; McGeown et al., 2009) and increase activity in the prefrontal attentional system (Deeley et al., 2012). Individual differences in hypnotizability have been proposed to be associated with the efficiency of the frontal attention system, and reduced functional connectivity, reflecting functional dissociation of conflict monitoring and cognitive control processes (Egner et al., 2005). Recent reviews by

Landry, Lifshitz, and Raz (2017), De Benedittis (2015) and Vanhaudenhuyse, Laureys, and Faymonville (2014) have summarized the neuroimaging results of hypnosis studies. In particular, Terhune et al. (2017) have provided a synthesis of the current knowledge regarding top-down regulation of human consciousness and perception in hypnosis. They, however, had to conclude that the roles of the different cortical and subcortical regions and their specific cognitive mechanisms in the implementation of top-down control that influences responsiveness to suggestions remain poorly understood.

Electrical brain oscillations as potential indices of hypnosis have been the focus of interest in many studies (see, e.g., Halsband & Wolf, 2019; Jensen, Adachi, Hakimian, 2015), and the first studies already emerged half a century ago (Galbraith, London, Leibovitz, Cooper, & Hart, 1970; Tebecis, Provins, Farnbach, & Pentony, 1975). Brain oscillations are estimated in the EEG frequency domain which has traditionally been divided into several frequency bands, that is, delta, theta, alpha, beta and gamma bands. *Delta oscillations* (1–4 Hz) are related to, for instance, attention, motivation and salience detection (Knyazev, 2012), reward systems of the brain (Knyazev, 2007), hunger, sexual arousal and sustained pain (Knyazev, 2012), and inhibitory modulation when accomplishing a task (Harmony, 2013). *Theta oscillations* (4–8 Hz) have been associated with orienting, attention, voluntary movement, working memory operations, memory encoding and retrieval (Buzsaki, 2005) and cognitive performance in memory tasks (Buzsaki, 2006). *Alpha oscillations* (8–13 Hz) are strongly associated with reductions in visual attention (Clayton, Yeung, & Cohen Kadosh, 2018) and observed to attenuate during mentally loading cognitive tasks such as arithmetic (Buzsaki, 2006). They typically increase with memory demands (Basar & Guntekin, 2012) and in the temporal regulation of perception (Clayton et al., 2018). *Beta oscillations* (13–25 Hz) are typically associated with motor activity (Etchell, Johnson, & Sowman, 2014) and high arousal (Ramautar, Romeijn, Gomez-Herrero, Piantoni, & Van Someren, 2013). They have been suggested to signal the maintenance of the sensorimotor status quo (Engel & Fries, 2010) and to play a role in the brain's ability to represent temporal information (Etchell et al., 2014). *Gamma oscillations* (>25 Hz) are typically associated with working-memory operations and selective attention, and they are modulated by the characteristics of the sensory input (Jia & Kohn, 2011), appearing to depend on the attributes and the class of the stimuli such as grating or color (Bartoli et al., 2019).

According to a recent review of brain oscillation studies of hypnosis (Jensen et al., 2015), hypnosis seems to be most consistently linked to an increase in theta power (see also Sabourin, Cutcomb, Crawford, & Pribram, 1990; Williams & Gruzelier, 2001) and possibly also to changes in gamma activity. However, opposite findings have also been reported, as some more recent studies have not observed hypnosis-related power changes in any EEG frequency bands (Jamieson & Burgess, 2014; White, Ciorciari, Carbis, & Liley, 2008). One study with a remarkably large sample size (28 high and 19 low hypnotizables) found an alpha2 power increase during hypnosis, but no results for any other EEG bands were reported (Terhune, Cardena, & Lindgren, 2011a).

When comparing highly hypnotizable subjects to lows in the wake state, highly hypnotizables have exhibited more theta power in most studies (Graffin, Ray, & Lundy, 1995; Kirenskaya, Novototsky-Vlasov, & Zvonikov, 2011; Vanhaudenhuyse et al., 2014), yet findings with no theta differences between the groups have also been reported (De Pascalis, 1999). Further research on the role of the theta oscillations as an indicator of hypnotizability is thus warranted (Terhune et al., 2017).

Gamma activity has been shown to be influenced by hypnosis and suggestions in a number of studies (e.g. De Pascalis, 1999; De Pascalis et al., 1989; De Pascalis, Ray, Tranquillo, & D'Amigo, 1998), but the direction of the effects has not been consistent. This inconsistency may depend on factors related to the EEG measurement, the nature of the suggestions, or the experimental setup (Jensen et al., 2015). Thus, the research findings concerning the EEG correlates of hypnosis and hypnotic suggestions have been rather heterogeneous, inconsistent and difficult to interpret (Cardena, Jönsson, Terhune, & Marcusson-Clavertz, 2013).

2.3.3 Mismatch negativity and hypnosis

There are only a few studies on the effects of hypnosis on the MMN. Jamieson, Dwivedi, and Gruzelier (2005) recorded MMNs in 11 low- and 12 high-hypnotizable subjects in pre-hypnosis, neutral hypnosis and post-hypnosis conditions. They observed that the frontal MMN amplitude increased during neutral hypnosis and then decreased in the post-hypnosis condition for both hypnotizability groups. In a study with a single highly hypnotizable subject, Kallio, Revonsuo, Lauerma, Hämäläinen, and Lang (1999) observed that the MMN amplitude to a pitch change increased in the neutral hypnosis condition when compared to pre-hypnosis. A few years later, in another single-subject study with the same subject, a diminished MMN amplitude to a pitch change was identified when she was experiencing visual and audiovisual hypnotically induced hallucinations (Kallio, Revonsuo, & Lang, 2005).

The first and thus far the only published multiple-subject study investigating the possible effect of hypnotic suggestions on the MMN was conducted by Facco et al. (2014). Their suggestions were intended to alter their subjects' perception of the auditory stimuli and to create a kind of amusia, a condition in which the individual is unable to recognize rhythms or melodies. The study was carried out by removing with hypnotic suggestions the subjects' ability to recognize deviant rhythms, that is, occasional changes in the duration of sinusoidal tones (standard tones 50 ms; deviant tones 100 ms, delivered with an interstimulus interval varying between 1020–1100 ms). The authors recorded MMNs from five highly and five non-highly hypnotizable subjects in pre-hypnosis and hypnotic-suggestion conditions in order to evaluate the effect of this "hypnotically induced amusia for rhythm" on the MMN. The MMN amplitude was reported to be significantly diminished during this condition but only in the highly hypnotizable subjects. Their results indicated that in highly hypnotizable subjects, it is possible to influence the brain's pre-attentive auditory information processing by hypnotic suggestions.

2.3.4 Behavioral performance and hypnosis

In a study by Kallio, Revonsuo, Hämäläinen, Markela, and Gruzelier (2001), several attentional or executive tasks were employed. The authors observed that in neutral hypnosis, RTs increased in simple RT and vigilance tasks in both low and high hypnotizable subjects when compared to the non-hypnosis condition. Thus, hypnosis seemed to slightly impair the behavioral performance.

In attention research, the Stroop task is one of the most studied tasks (MacLeod, 1992) and has also been used to study behavioral effects of hypnotic suggestions (Raz, Moreno-Iniguez, Martin, & Zhu, 2007). The Stroop effect (i.e., the delay in naming the color of the printed word when the color and the semantic meaning of the word are incongruent, e.g., the word "red" printed with blue ink) is thought to reflect the difficulty in inhibiting highly automatized cognitive processes (MacLeod, 1992). There is strong evidence that the Stroop effect can be reduced or even eliminated by using posthypnotic suggestions according to which the words are, for example, meaningless symbols (MacLeod & Sheehan, 2003; Raz, Fan, & Posner, 2005; Raz, Kirsch, Pollard, & Nitkin-Kaner, 2006; Raz, Shapiro, Fan & Posner, 2002; Zahedi et al., 2017). In these studies, the effect was achieved only in highly hypnotizable subjects. In one study, the reduction of the Stroop effect, although to a lesser extent, was also observed in low hypnotizable subjects (Raz & Campbell, 2011). In addition, non-hypnotic suggestions have also reduced the Stroop effect (Raz et al., 2006). Consequently, in the Stroop task suggestions can attenuate the activation of highly automatized cognitive processes. An opposite ability of suggestions has also been shown, where initially controlled processes have been shifted to a more automatic mode (Lifshitz, Aubert Bonn, Fischer, Kashem, & Raz, 2013).

In a study by Iani, Ricci, Gherri, and Rubichi (2006), a posthypnotic suggestion was aimed at increasing the target's discriminability in a Flanker task (Eriksen & Eriksen, 1974). In this task, a central target stimulus is presented simultaneously with two distractor stimuli (flankers) that have the same or a different identity as the target, and participants are instructed to indicate the target's identity by pressing one of two keys. To make the correct response, participants need to select the relevant information and inhibit the surrounding irrelevant information (the flankers). The posthypnotic suggestion effectively eliminated the flanker compatibility effect (as calculated by subtracting RTs on congruent trials from RTs on incongruent trials) in highly hypnotizable subjects, whereas low-hypnotizable subjects did not show any reduction in the effect. In addition, a similar suggestion given without hypnosis was not sufficient to reduce the flanker compatibility effects in the high hypnotizables.

The Simon effect (Simon & Rudell, 1967) has also been reduced by posthypnotic suggestions in highly hypnotizable subjects (Iani, Ricci, Baroni, and Rubichi (2009). In this paradigm, participants are required to respond to a non-spatial stimulus feature (e.g., stimulus color or shape) by pressing a spatially-defined response (e.g., a left or right response key). Even though the stimulus location is completely irrelevant for performing the task, responses are faster and more accurate on trials where the stimulus and the response position correspond to each other, compared to trials where they do not correspond. The effect is also evident with centrally-presented stimuli which convey spatial information through meaning, such as arrows pointing to the left or right (used in the afore-mentioned study).

Some findings also indicate that by using hypnotic suggestions, it is possible to influence highly automatized or even seemingly "hard-wired" information processing such as color perception (Kallio & Koivisto, 2013; Koivisto et al., 2013). However, this may only be possible with some of the most highly hypnotizable individuals. Kallio et al. (2017), by using hypnotic suggestions, induced a kind of form-color synaesthesia in which symbols (circles, crosses, squares) in an array were suggested to always have a certain color. In a Stroop-type naming task (where the task was to name the symbol colors as quickly and accurately as possible), three highly hypnotizable participants showed a strong synaesthesia-type association between symbol and color. Control participants who tried to mimic the task using cognitive strategies showed a very different response pattern, being clearly slower in the task. The authors proposed that targeted, preconsciously triggered associations and perceptual changes typical to congenital synaesthesia can rapidly be induced by hypnotic suggestions in highly hypnotizable individuals.

3 Aims of the study

Terhune et al. (2017) described hypnosis as a unique form of top-down regulation, where higher (e.g., frontal) brain areas exert an influence on processing at the lower levels. The present thesis investigates whether such hypnotic top-down effects are able to modulate brain oscillations, influence involuntary and voluntary auditory information processing, or produce a long-lasting symptom reduction in adults with ADHD.

The present thesis has three general aims. It explores:

(1) whether hypnosis in highly hypnotizable participants differs from the normal wake state from the perspective of brain oscillations (spectral power density).

(2) whether hypnosis and hypnotic suggestions can, in healthy control participants, be used to modulate auditory attentional mechanisms in two domains: involuntary bottom-up pre-attentive information processing (as reflected by MMN) and voluntary top-down processing in sustained attentional tasks (as reflected by behavioral performance).

(3) whether hypnosis can be applied for treating adults with ADHD. More specifically, it was studied whether hypnotherapy can be used to relieve the ADHD symptoms and if hypnotic suggestions can improve voluntary top-down processing in sustained attention tasks.

In addition to these general aims, four study-specific research questions were investigated in the original studies, as shown in Figure 1. As indicated in the literature review section, there exist only a few earlier studies investigating the effects of hypnosis on MMN, and no previous follow-up studies of hypnotherapy in treating adults with ADHD.

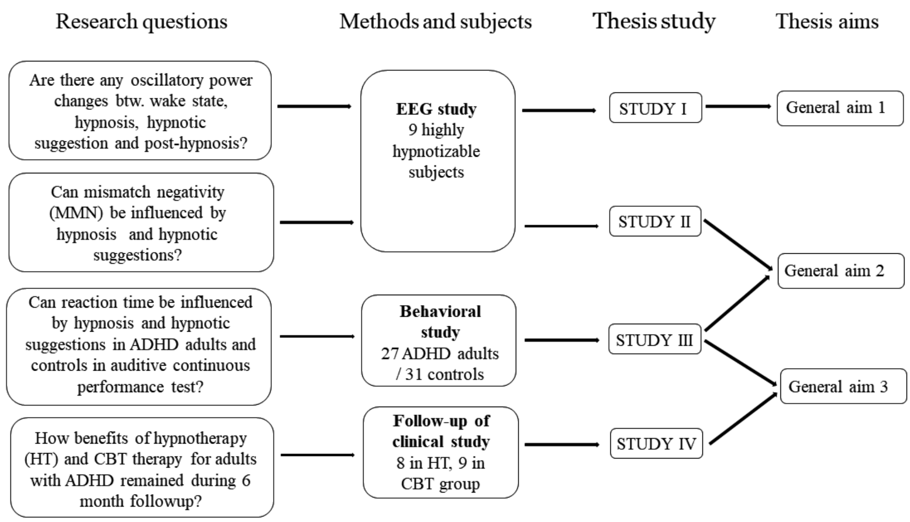

Figure 1 Four study-specific research questions and their methods used to address the three general aims of the thesis

4 Methods

4.1 Study participants

The demographic data of the participants in Studies I–IV are presented in Table 1.

Table 1. The characteristics of participants in Studies I–IV

	Studies I–II	Study III		Study IV	
		ADHD	Controls	HT[c]	CBT[c]
Participants (n)	9	27	31	8	9
Age: mean (range)	25.7 (20–37)	31.7 (22–45)	25.2 (19–45)	32.1 (21–42)	39.0 (25–49)
Gender: male/female	1/8	9/18	6/25	3/5	3/6
Education: compulsory /additional (n) [a]	0/9	5/22	0/31	2/6	1/8
Working or studying: yes / no [b]	9/0	23/4	31/0	6/2	4/5
ADHD diagnosis (n)/all	1	all	0	all	all
ADHD medication: yes / yes, but not in use / no	0/0/9	11/6/10	0/0/31	6/0/2	5/0/4[f]
ADHD medication change at follow-up, (n) participants	-	-	-	1	4
Antidepressant medication (n)	0	3	1	1	2
Psychiatric comorbidity (n)	0	12	2	4	7
depression (n)	0	10	2	2[d]	6
anxiety (n)	0	4	0	3[d]	0
personality disorder (n)	0	2	0	1	1
ASRS score: mean (SD)	-	49.4 (9.3)	16.0 (6.7)	-	-
SCL-90 score: mean (SD)	-	161.4 (41.3)	114.7 (18.4)	87.6 (46.5)	92.3 (19.9)
WURS score: mean (SD)	-	-	-	50.9 (18.5)	53.1 (13.0)
Severity of ADHD (CGI): mean (SD)	-	-	-	3.6 (0.7)	3.8 (0.8)
HGSHS:A score: mean (SD)	10.1 (0.9)[e]	7.2 (2.5)	6.4 (2.7)	5.9 (3.1)	-

NOTES: [a] Compulsory = the participant had completed only lower secondary education (i.e., Finnish compulsory education)
[b] Working/studying yes = the participant was working (at least a half-time job) or studying
[c] The demographic data at the beginning of the intervention
[d] Two participants had both depression and anxiety diagnoses
[e] All participants were highly hypnotizables, range: 9–11
[f] One of five participants ceased to use medication at treatment time but used medication during follow-up
HT = Hypnotherapy
CBT= Cognitive Behavioral Therapy
ASRS = Adult ADHD Self-report Scale
SD = Standard deviation
SCL = Symptom Check List
WURS = Wender Utah Rating Scale
CGI = Clinical Global Impressions
HGSHS:A = Harvard Group Scale of Hypnotic Susceptibility, Form A

Where applicable, the hypnotizability of the participants was measured using the Finnish version (Kallio, 1996; Kallio & Ihamuotila, 1999) of the Harvard Group Scale of Hypnotic Susceptibility, Form A (HGSHS:A) (Shor & Orne, 1962). The inclusion criteria for participation in Studies I–IV are presented in Table 2. Included and excluded participants, as well as those who canceled/discontinued participation in Studies I–IV are shown in Figure 2.

Table 2. The inclusion criteria of participants in Studies I–IV

Study I–II	**Study III**	**Study IV**
(1) 18–45 years of age (2) no diagnosis of psychosis or bipolar disorder (3) no neurological disorders, apart from migraine (4) no current severe depression	(1) 18–45 years of age (2) no diagnosis of psychosis or bipolar disorder (3) no current severe depression The participants for the ADHD group: ADHD diagnosis made by a physician The participants for the control group: no ADHD diagnosis or ADHD symptoms	(1) 18–49 years of age (2) ADHD diagnosis made by a physician (3) no diagnosis of psychosis, severe depression, or paranoia (4) deficits of attention, executive functions, or working memory found in neuropsychological evaluation (5) no current alcohol dependency or drug use (6) not retired (7) no participation in previous group rehabilitation study (of the research group) (8) currently undergoing no other psychological rehabilitation (9) no medication or medication that has been stable for at least three months

Studies I and II. The two studies had mutual participants, procedures and EEG measurement parameters, but the research questions and the EEG analysis methods were different. The participants were recruited through advertisements in the mailing lists of students of psychology and educational sciences at the University of Helsinki. The hypnotizability of 48 participants was measured, and all highly hypnotizable participants (N=9; a score of nine or more in HGSHS:A, the maximum score being 12; all were right-handed students) were selected for the EEG measurement session.

Study III. The participants were recruited through advertisement in an ADHD magazine, in an adult ADHD internet discussion forum and by informing local physicians and clinics specialized in treating adults with ADHD. The control participants were recruited from the mailing list of psychology students at the University of Helsinki. There were a total of 27 participants in the ADHD group and 31 in the control group.

Study IV. The six-month follow-up data were originally collected in earlier studies (Virta et al., 2010a, 2010b) and analyzed for the purposes of Study IV. Table 2 describes the original inclusion criteria. The participants were originally randomized to three treatment groups (hypnotherapy, CBT, cognitive training) and a control group. Because the participants in the studies gained benefit only from hypnotherapy and CBT treatments, the participants who received these two interventions were selected for Study IV. There were eight follow-up participants in the hypnotherapy treatment, and nine follow-up participants in the CBT treatment.

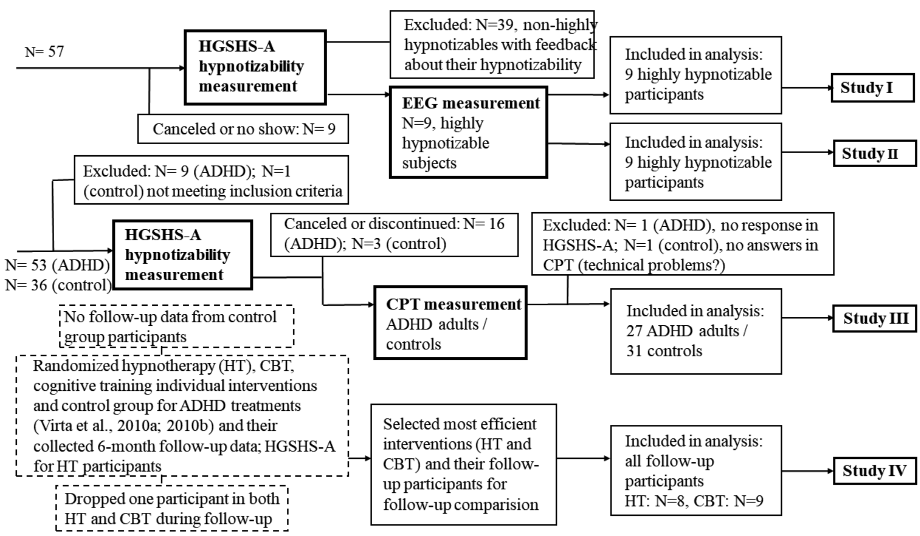

Figure 2 Flowchart for participant inclusion/exclusion and methods in Studies I–IV

4.2 Stimuli

4.2.1 Stimuli in the EEG experiment (Studies I and II)

Auditory and visual stimuli were presented to the participants during the EEG recording. Pure sinusoidal tones (duration 100 ms with linear 10-ms rise and fall times) were used as the auditory stimuli. During each condition, standard tones (500 Hz; p=0.82) and deviant tones (520 Hz, p=0.18) were presented in an oddball paradigm, in a random order in blocks of 737 stimuli with a 400-ms interstimulus interval (ISI). The stimulation lasted 6 min 8 seconds per condition. The tones (with intensity about 56 dB SPL at the participant's ear level) were presented from two loudspeakers, positioned on the right and left side of the participant at about 100–110 cm distance. The opening angle of the loudspeakers was about 160–170°.

A silent nature video of a calmly flowing narrow forest river was used as a visual stimulus. The video was commercially sold for relaxation purposes (OutpostFX AB, www.outpostfx.com). The video was shown on an 18-inch display, which was located in front of the participant at a distance of about 140–150 cm from the participant's eyes. For further details of the auditory and visual stimulation, see Hiltunen, Virta, Kallio, and Paavilainen (2019).

4.2.2 Stimuli in the behavioral experiment (Study III)

Auditory stimuli, in the form of recorded spoken letters, were presented in the behavioral performance experiment using a modified CPT paradigm. Each stimulus block (one three-minute block per each of the four conditions) contained 100 auditory stimuli (letters), of which 30% were target letters. The target letter was different (A, I, U, or Y) in each of the four conditions and the order of the conditions was counterbalanced between the participants. The ISI was 1800 ms. The intensity of the stimuli was adjusted individually to a comfortable level during a practice session (since many ADHD participants are hypersensitive to various stimuli).

4.3 Procedures

All participants in Studies I–IV completed a questionnaire about their work, education, health and medication.

4.3.1 EEG experiment (Studies I and II)

In Studies I and II, the participant was seated in a reclining armchair in an acoustically and electrically shielded room. The experimenter, who administered hypnosis, sat to the right and behind the participant. Before starting the experiment, the participant was told that his/her task in all experimental conditions was just to relax and to watch the video, there being no need to attend to the tones in the environment. The participant was also asked to avoid, if possible, excessive eye blinking during the video watching. The four experimental conditions (lasting, in total, approximately 45 minutes) were presented in the following order:
1) Pre-hypnosis condition (PrH): The participant was instructed to watch the video while the auditory stimuli were delivered.
2) Neutral hypnosis condition (HY): Before the presentation of the auditory stimuli, a hypnotic induction, consisting of eye fixation, closing eyes, relaxation and deepening of hypnosis by counting, was carried out in a structured way, but allowing some personal modification (e.g., the time of closing the eyes). After the induction, the participant was subsequently asked to open his/her eyes and start watching the video. Thereafter, the auditory stimulus block was started. A few more suggestions for intensifying the depth of hypnosis were given once in the middle of the condition. At

the end of the auditory stimulation, the experimenter asked the participant to close his/her eyes.
3) Hypnotic-suggestion condition (SU): The experimenter first gave the suggestions to alter the participant's perception of the auditory tone stimuli. The suggestions were formulated to suggest that all the tone beeps will sound exactly similar in pitch and are heard softly in the background without any meaning. Then, the experimenter asked the participant to open his/her eyes and watch the video. Thereafter, the auditory stimulation started. Once in the middle of the condition, a few more suggestions were given to intensify the depth of hypnosis and the altered tone perception. At the end of the auditory stimulation, the experimenter asked the participant to close his/her eyes. Thereafter, a hypnotic reversal procedure (with the termination of suggestions) was administered. During the procedure, the participant opened his/her eyes.
4) Post-hypnosis condition (PoH): The participant was instructed to watch the video and the last auditory stimulus block was delivered.

For further details on the procedure and the contents of hypnotic suggestions, see Hiltunen et al. (2019).

4.3.2 Behavioral performance test (Study III)

The participants were tested individually using a modification of a CPT. One CPT stimulus block (lasting three minutes) was presented in each condition and the participant's task was to detect the target letter by pressing a button. First, the participant participated in a short practice session to become familiar with the task. The participants received identical instructions in all four experimental conditions. The instructions were formulated as follows: *After a while, you will hear letters. Press the button as quickly and accurately as possible when you hear the target letter. The target letter is A/I/U/Y. The task begins now.*

In the experimental session, four conditions were presented in the following order:
1) Pre-hypnosis condition (PrH): The participant carried out the task with the auditory stimuli.
2) Neutral-hypnosis condition (HY): Before the task and the presentation of the auditory stimuli, a hypnotic induction (lasting about 8 minutes) was carried out in a structured way, while allowing for some personal modification (time to close the eyes). Then, the task was executed by the participant.
3) Hypnotic-suggestion condition (SU): First, hypnotic suggestions for accuracy and speed were administered by the experimenter. Thereafter, the participant carried out the task. After the task, a hypnotic reversal procedure and termination of suggestion (with special emphasis on the normalization of attention and speed) were administered.
4) Post-hypnosis condition (PoH): The participant carried out the task.

The whole procedure (preparation, induction, four conditions, termination) lasted approximately 30 minutes. The induction, suggestions and hypnosis reversal procedure are described in more detail in Virta, Hiltunen, Mattsson, and Kallio (2015).

4.3.3 Clinical follow-up study treatments (Study IV)

Study IV consisted of a six-month follow-up of two ADHD individual treatments, hypnotherapy and CBT. The treatments were designed and implemented by Virta et al. (2010a) and Virta et al. (2010b), respectively, and the therapeutic procedures are discussed in more detail in the original publications. The treatment contents were the following:

The hypnotherapy treatment was theoretically grounded in cognitive hypnotherapy and consisted of a set of hypnotherapeutic interventions. The themes of the treatment sessions were selected to cover the main ADHD symptoms set out in the DSM-IV diagnostic criteria (American Psychiatric Association, 1994), and by Brown (2000, 2005) when suitable for the hypnotherapy. The hypnotherapy consisted of 10 weekly sessions led by a psychologist experienced in hypnosis and ADHD. The themes and contents of the sessions were: (1) stillness/calming, (2) motivation to change, (3) attention, (4) initiation of activities, (5) memory, (6) self-esteem, (7–9) individually chosen topics (e.g., fear of social situations, anger management, reducing impulsivity, a second treatment of previous themes) and (10) continuation of the process. Each 40–60-minute session followed the same procedure: discussion of the preceding session, discussion of the current theme, hypnotic induction, hypnotherapy, and discussion. In the hypnotherapy part, the psychologist followed a pre-written, semi-structured manual.

The CBT treatment consisted of 10 weekly sessions led by a psychologist experienced in ADHD and training in CBT. The themes of the sessions in the CBT treatment were selected to cover the main ADHD symptoms set out in the DSM-IV diagnostic criteria (American Psychiatric Association, 1994), and by Brown (2000; 2005). The themes and the contents were the following in the 10 sessions: (1) treatment goals and symptoms of ADHD, (2) attention, (3) motivation and initiation of activities, (4) organization and planning, (5) stress management and relaxation, (6) self-esteem, (7–9) individually chosen topics (e.g., memory techniques, anger management, managing impulsivity, a second treatment of previous themes), and (10) continuation of the process. The psychologist followed a written, semi-structured manual (Virta et al., 2009) and used a whiteboard and written material for illustrating the most important points and tasks at hand. Additionally, individually tailored homework, as typical for CBT, was given. Each 60-minute session followed the same procedure: discussion of the previous homework and theme, introduction and discussion of the current theme, assignment of the new homework, and distribution of the written material.

4.3.4 Outcome measures

Studies I and II. The EEG was recorded with a Biosemi measurement system (www.biosemi.com, 0–102.4 Hz bandpass, 512 Hz sampling rate), with a 64-channel cap from the same manufacturer. In addition, separate electrodes were attached to the left and right mastoids and the tip of the nose. Eye movements were monitored with electrodes on the right and left canthi and below the left eye. The grounding electrode (CMS) was attached to the back of the head. Data filtering and artifact correction procedures varied slightly across studies, see separate sections for Studies I and II.

Calculation of spectral densities (Study I). The EEG data were preprocessed using BESA 7.0 software (BESA GmbH, Germany). First, signals were filtered (0.53–45 Hz, 6 dB/octave, forward and 24 dB/octave, zero phase). Ocular artifacts were corrected using the automatic Principal Component Analysis (PCA) artifact correction tool with the default thresholds (150 µV for HEOG amplitude and 250 µV for VEOG/blink). The automatic artifact correction did not work for one of the participants in two conditions. In these cases, instead of automatic correction, a prominent eye blink was manually selected (from onset to offset visible on frontal electrodes) to represent the artifact topography for the same PCA process described above. The data were re-referenced to the average of the mastoids. After the visual inspection of the data, continuously noisy channels were interpolated for five participants (for each of them, 1 out of the 10 final electrodes used in the power analysis had to be interpolated from the original 64 electrodes).

The rest of the analysis was done in Matlab R2016a (The MathWorks, USA). Data exported from BESA were first epoched according to the experimental conditions. Power spectral densities were calculated using the Spectopo function in the EEGLAB toolbox (www.sccn.ucsd.edu/eeglab; version 14.1.2) which uses Welch's method (Welch, 1967) for the estimation and results in the power spectral density being in the unit of 10*log_10(\µV^2/Hz). The analysis window was four seconds with a 50% overlap, resulting in a frequency resolution of 0.25 Hz with a sampling rate of 512 Hz. The mean power spectral density over each condition was calculated in nine frequency bands: delta (1–3.5 Hz), theta1 (3.5–6 Hz), theta2 (6–8 Hz), alpha1 (8–10 Hz), alpha2 (10–11.5 Hz), alpha3 (11.5–13 Hz), beta1 (13–19 Hz), beta2 (19–27 Hz), and gamma (27–45 Hz). Altogether, ten electrodes (five electrodes from each hemisphere) were used for the analysis: Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, and O2. SPSS statistics 25 (IBM, USA) were used in the statistical analysis of the mean power estimations of the electrodes.

ERP averaging (Study II). ERPs to the standard and deviant tones were averaged with Matlab R2016a using an EEGLAB toolbox (www.sccn.ucsd.edu/eeglab). The EEG was filtered with a 0.5 to 30 Hz bandpass and re-referenced to the average of the right and left mastoid electrodes. When the MMN signal is small (e.g., when the frequency difference between a standard and a deviant tone is relatively small), it is recommended to re-reference the EEG data against the mastoids, since this adds the "negative" and "positive" parts of the MMN, resulting in a larger response with a higher signal-to-noise ratio (Kujala, Tervaniemi, & Schroger, 2007). Then the EEG was cut into epochs starting 100 ms before the onset of the tone and ending 500 ms after the onset. Epochs containing voltage changes exceeding ±100 μV (e.g., artifacts related to eye movements or muscle tension) were rejected. The remaining epochs were averaged to obtain the ERPs separately to the standard and deviant tones in each condition. The 100-ms prestimulus period served as the baseline for ERP amplitude measurements. The grand-average difference waveforms were calculated by subtracting the standard-tone ERPs from the ERPs to the deviant tones.

The MMNs were measured by calculating the mean amplitudes from the standard and deviant-stimulus ERPs during 150–250 ms at Fz, F3, and F4 electrodes, since the MMN is typically maximal over the fronto-central areas (Kujala et al., 2007). The 100-ms latency window was visually selected on the basis of the grand-average difference waves. In order to obtain reliable ERPs, Independent Component Analysis (ICA) for the eye movement artifact correction was used for one participant who exhibited a lot of eye blinks during the EEG recordings. For this participant, one to two well-characterized ICA components for eye blinks and lateral eye movements were visually identified. For selecting and rejecting these artifactual ICA components, visual inspection of the component scalp maps, power spectrum, and raw activity were used. For another participant, one electrode with a bad contact had to be interpolated from the surrounding electrodes.

Study III. RTs and the number of errors (omission and commission) were measured. The experiment with a three-minute CPT was found too short to obtain a sufficient amount of errors for reliable comparisons. Its results were excluded from the present thesis, but can be found in Virta et al. (2015). For other outcome measures of Study III, see Table 3.

Study IV. The follow-up period was six months and the participants of the two treatments were evaluated after three (T3) and six months (T4) from the end of the treatment (T2). Self-report questionnaires and independent evaluation were used as outcome measures (see Table 3). In the earlier studies (Virta et al., 2010a, 2010b), data were collected before the treatment (T1), immediately after the treatment (T2), and three (T3) and six months (T4) after the end of the treatment. T1 and T2 results were reported in those two studies. The independent evaluator was a clinical psychologist experienced in adult ADHD who was blind to the treatment group of the participants.

Table 3. Outcome measures in Studies III–IV

Outcome measures	Description	Study and details
World Health Organization's Adult ADHD Self-report Scale (ASRS) (Kessler et al., 2005)	An 18-item self-report scale reflecting the DSM-IV criteria for ADHD modified for adults	III
Symptom Check List (SCL-90) (Derogatis, Lipman, & Covi, 1973)	A 90-item self-report scale for the measurement of psychiatric symptoms. Several subscales can be calculated, e.g., for anxiety and depression. Total scores and subscale scores were used in the analyses of the follow-up period. The higher the scores, the more severe the symptoms.	III, IV. In Study III, only total score was used. In Study IV, total scores and subscale scores were used in the analysis.
Sum score of ADHD symptoms (SCL-16) from SCL-90 (Hesslinger et al., 2002)	A 16-item sum score reflecting the characteristics prominent in ADHD which was calculated from the SCL-90. The higher the scores, the more severe the symptoms.	IV
Brown Attention Deficit Disorder Scale – Adult Version (BADDS) (Brown, 1996)	A 40-item inventory from which the self-report version was used. From the BADDS, a total score and scores of the five sub-domains of activation, attention, effort, affect, and memory were derived. Higher scores indicate a more severe impairment.	IV
Beck Depression Inventory – Second Edition (BDI-II) (Beck, Steer, & Brown, 1996)	A 21-item scale that evaluates self-reported symptoms of depression. The higher the scores, the more severe the symptoms.	IV
Quality of Life Enjoyment and Satisfaction Questionnaire (Q-LES-Q) (Endicott, Nee, Harrison, & Blumenthal, 1993)	A 93-item self-report scale, from which 91 items can be grouped into 8 subscales that indicate: satisfaction with physical health, subjective feelings, work, household duties, school, leisure activities, social relationships, and general activities. Higher scores indicate greater enjoyment or satisfaction. The scores are reported as a percentage of the maximum score.	IV. In the present thesis, only the main score of Q-LES-Q was reported from Study IV.
Clinical Global Impressions (CGI) (Guy, 1976)	CGI was completed by an independent evaluator. At T1, severity of ADHD was evaluated according to the CGI, which is a single seven-point rating scale of functioning varying from 1 = normal, not at all ill, to 7 = among the most extremely ill patients. At T2, T3 and T4, global improvement was assessed using a seven-point scale varying from 1 = very much improved, to 7 = very much worse (4 = no change). Each assessment was performed in comparison to the participant's preceding evaluation.	IV

T1 = pre-treatment
T2 = post-treatment
T3 = three-month follow-up
T4 = six-month follow-up

4.3.5 Statistical analysis

Repeated-measures analyses of variance (rmANOVA) were used in all four studies. The effect sizes in rmANOVAs were quantified by partial eta squared. The significance level was set at $p < 0.05$ in all the analyses.

In Study I, nine 2 × 5 × 4 rmANOVAs, one for each frequency band, were performed with lateralization (left- and right-side electrodes), anteriority/posteriority (frontopolar, frontal, central, parietal and occipital electrode pairs) and condition (PrH, HY, SU, PoH) as the within-subject factors. The measured power spectral density at each electrode served as the dependent variable. Greenhouse–Geisser corrections for the lack of sphericity were applied when appropriate and Bonferroni-corrected post-hoc tests were conducted whenever necessary. Based on the model diagnostics, the distributional assumptions of the ANOVA were met. Although there were slight deviations from normality in the observed variables, the model residuals were normally distributed.

In Study II, 2 × 3 × 4 rmANOVA was performed with stimulus type (standard/deviant), electrode (F3, Fz, F4) and condition (PrH, HY, SU, PoH) as the within-subject factors. The MMN mean amplitude during 150–250 ms at the three electrodes served as the dependent variable. F3 and F4 were included in the analysis to reveal possible hemisphere differences in the MMN amplitudes. Also, the subjective hypnosis depth values were analyzed with rmANOVA. The Greenhouse–Geisser correction was applied to all of the degrees of freedom of the F-tests.

In Study III, two-way mixed design 2 × 4 rmANOVA was carried out to investigate RT (dependent variable) differences between the two groups. Condition (PrH, HY, SU, PoH) served as the within-subject factor. Greenhouse–Geisser correction was applied to all degrees of freedom in the F-tests. Normality assumptions were assessed using the Shapiro–Wilk test together with inspecting histograms and plots of the residuals. All analyses were re-run after applying a 1/x transformation to all the RTs to ensure the validity of the results. In addition, the analyses were re-run using the median RT of each participant in each condition to ensure that the few long RTs did not distort the results. None of the main conclusions were altered in these analyses. To better understand the differences in RTs between the experimental conditions, four within-group planned comparisons were carried out using paired-samples t-tests separately for the two experimental groups. The p-values of these tests applied a Bonferroni correction and were reported for multiple comparisons, together with the effect sizes (Cohen's *d*) of the tests.

In Study IV, missing values on the questionnaires were substituted with that particular respondent's mean score. Distribution properties of the variables were inspected visually and with Shapiro–Wilk tests and parametric tests were chosen for the statistical analyses. Two-way mixed design 3 × 2 rmANOVA was carried out to find time x group interactions for the outcome variables at follow-up. Where Mauchly's test indicated violation of the sphericity assumption, Greenhouse–Geisser-corrected values were used. Paired samples t-tests were used for both groups separately for comparing T2 versus T4 outcomes. The T-tests were used mainly to approximate the directions of the treatment group differences found in ANOVA. The effect sizes (Cohen's *d*) in the most important t-test results were reported. Changes in Clinical Global Impressions (CGI) were analyzed using the chi-squared test (Fisher's exact test, χ^2).

4.4 Ethical considerations

All participants gave their written informed consent prior to participating in the study. All studies were conducted according to the Declaration of Helsinki and were approved by the University of Helsinki Ethical Review Board in the Humanities and Social and Behavioral Sciences (Studies I and II) or by the Ethics Committee of the Helsinki University Central Hospital (Studies III and IV). In the clinical study (Study IV), participants with ADHD diagnosis were originally evaluated by a psychiatrist to ensure that there were no contraindications for hypnosis. In all other studies, the background health information provided by the participants was compared with the inclusion criteria by the psychologist carrying out the study.

The identities of the participants were kept anonymous, and the methods were inherently non-invasive, consisting of hypnotizability group measurements, questionnaire results, interviews, interventions and EEG recordings, depending on the study. As a reward, the participants in the EEG recordings (Study I–II) were given culture and leisure vouchers worth 20 euros.

5 Results

The purpose of this section is to answer the four research questions presented in the section “Aims of the study” by summarizing the key findings of all four studies. A more detailed description of the complete results and observations can be found in the original publications.

5.1 Study I

Figure 3 shows the mean oscillatory powers in the four experimental conditions (PrH, HY, SU, PoH) at the lower frequency bands (<14 Hz) and Figure 4 those at the higher frequency bands (>14 Hz). No significant effects between the conditions were found in the theta1 ($F(3,24) = 0.20$, $p = 0.893$, $\eta p^2 = 0.03$) or theta2 ($F(3,24) = 0.16$, $p = 0.921$, $\eta p^2 = 0.02$) bands. In the other lower-frequency bands, no significant condition effects were found.

In the higher-frequency bands, no significant effects were found in the beta1 and beta2. In the gamma band, condition was found to have a significant effect ($F(3,24) = 3.63$, $p = 0.027$, $\eta p^2 = 0.31$). Post-hoc tests with Bonferroni correction revealed a significant difference between SU and PoH ($p = 0.029$) and an almost significant difference between HY and PoH conditions ($p = 0.055$). Thus, the two hypnosis-related conditions exhibited less gamma power than the PoH condition (see Figure 4).

No significant differences in laterality (nor laterality × condition interactions) were found in any of the frequency bands. Additionally, no statistically significant interactions were found between the conditions and the anteroposterior dimension, implying that hypnosis or hypnotic suggestions did not change the anteroposterior power distribution.

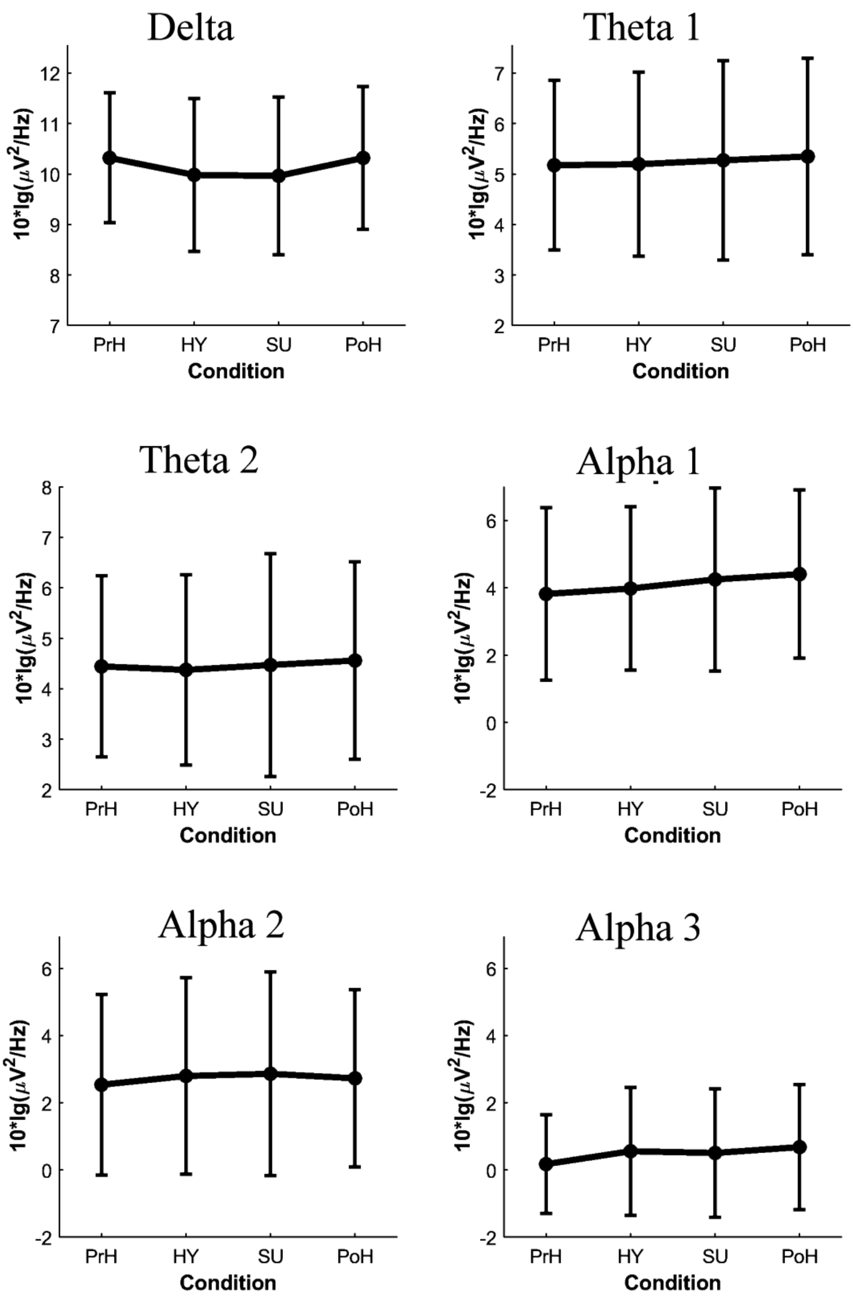

Figure 3 Mean oscillatory powers of the frequency bands up to 14 Hz (delta, theta1, theta2, alpha1, alpha2, alpha3) in the four experimental conditions. PrH = pre-hypnosis, HY = neutral hypnosis, SU = hypnotic suggestion, PoH = post-hypnosis. Error bars: 95% CI. NB the different scales in the panels.

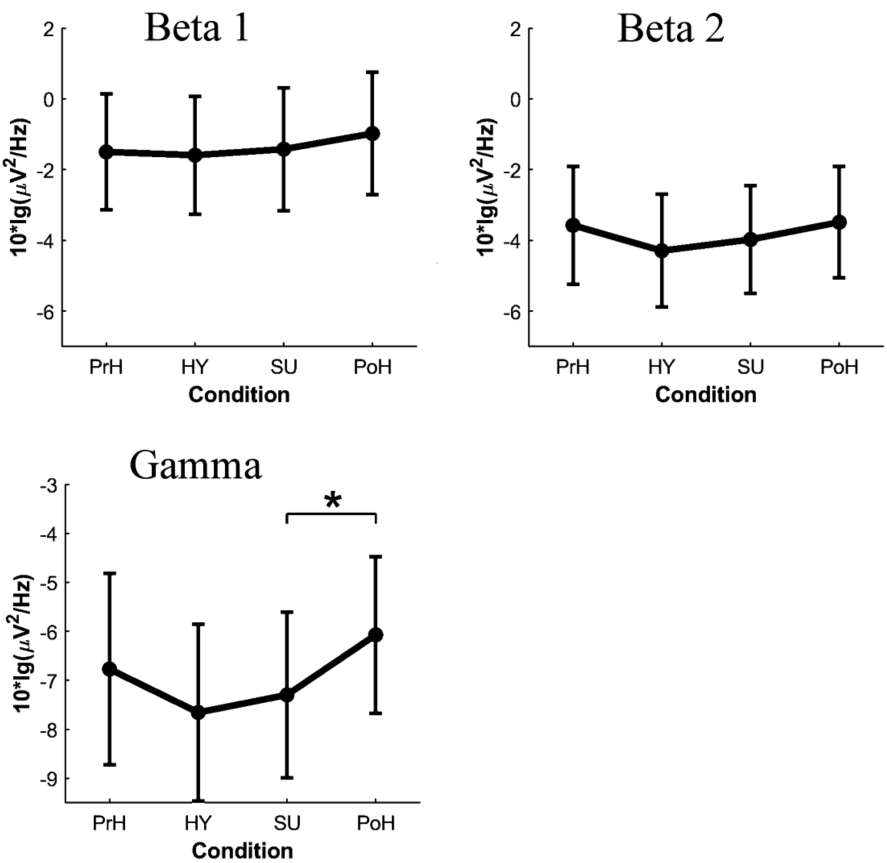

Figure 4 Mean oscillatory powers of the high frequency bands over 14 Hz (beta1, beta2, and gamma) in the four experimental conditions. PrH = pre-hypnosis, HY = neutral hypnosis, SU = hypnotic suggestion, PoH = post-hypnosis. Error bars: 95% CI. * = p < .05. NB the different scales in the panels.

5.2 Study II

ERPs at Fz to standard and deviant stimuli in the four experimental conditions (PrH, HY, SU, PoH) are presented in Figure 5. The ERPs to the deviants were negatively displaced relative to those to standards in all conditions. This negative displacement, starting at about 100 ms, is the MMN.

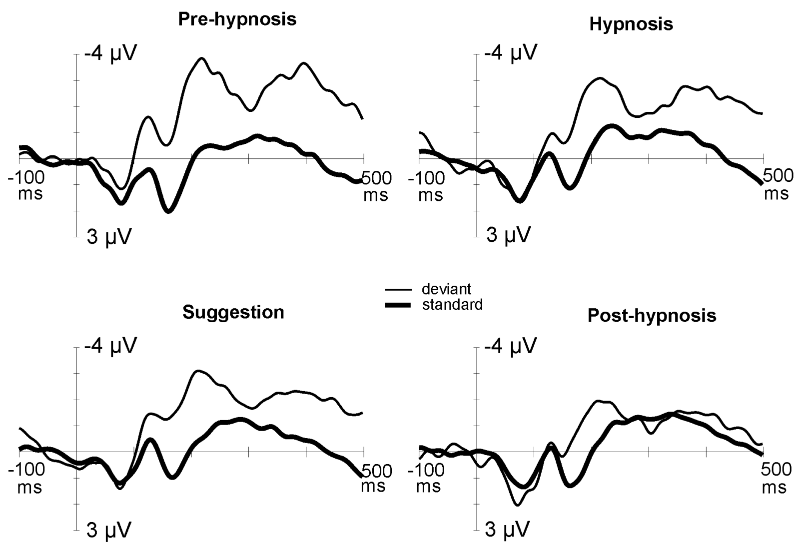

Figure 5 ERPs at Fz to standard (thick line) and to deviant (thin line) stimuli in the four conditions. Negativity is plotted upward.

Figure 6 presents the deviant minus standard difference waves, enabling the comparison of MMN amplitudes and latencies between the conditions. The MMN peaked at approximately 200 ms and its onset and offset latencies were rather similar between the conditions. The largest peak amplitude of MMN was observed in the PrH and the lowest in the PoH condition. As a trend, the MMN seemed to decrease in successive conditions, although the amplitudes in suggestion and hypnosis conditions were rather similar. No clear P3a component followed the MMN in any condition.

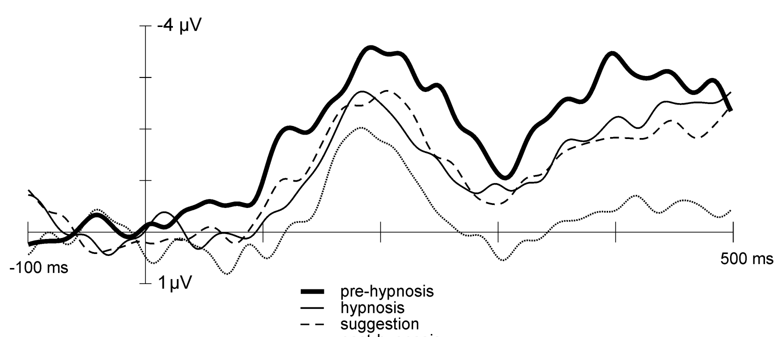

Figure 6 Deviant minus standard difference waves at Fz in the four conditions. The MMN was measured as the mean amplitude during 150–250 ms.

Since the MMN peaked in all conditions at around 200 ms, the MMNs were measured for the statistical analyses from the difference waves as their mean amplitudes during 150–250 ms. At Fz, the mean amplitudes and their standard deviations were as follows: PrH: -3.1 μV (1.3), HY: -2.1 μV (0.7), SU: -2.3 μV (1.9) and PoH: -1.4 μV (1.5). The 2 × 3 × 4 rmANOVA showed that the main effect of stimulus type (standard/deviant) was statistically significant ($F(1, 8) = 59.19$, $p < 0.001$, $\eta p^2 = 0.88$), confirming the presence of MMN in the ERPs. The main effects of condition ($F(2, 16) = 1.41$, $p > 0.05$, $\eta p^2 = 0.15$) or electrode ($F(1, 10) = 1.59$, $p > 0.05$, $\eta p^2 = 0.17$) were, however, not statistically significant. Most importantly, the stimulus type × condition interaction was not significant ($F(2, 14) = 2.97$, $p > 0.05$, $\eta p^2 = 0.27$), indicating that no statistical evidence for MMN amplitude differences between the conditions was found.

The depth of hypnosis in Studies I and II. The participants of Studies I and II were asked by the experimenter to subjectively evaluate their experienced depth of hypnosis (0–10) during the experimental conditions. The depth values for each condition were obtained by calculating the average of the values reported by each participant at the beginning and end of each condition. The mean subjective hypnosis depth values and their standard deviations in the four experimental conditions were as follows: PrH: 0.8 (0.9), HY: 5.8 (1.7), SU 5.7 (2.7), and PoH 0.9 (1.3). The rmANOVA showed that the subjective hypnosis depth values differed significantly between the hypnosis and non-hypnosis conditions ($F(2, 12) = 60.00$, $p < 0.001$, partial eta squared (ηp^2) = 0.88).

5.3 Study III

Mean RTs between the ADHD group and the control group in the PrH baseline condition did not differ significantly ($t(56) = 0.23$, $p = 0.82$). To examine whether the RTs in the ADHD and control groups differed across the conditions, a two-way mixed design 2 × 4 rmANOVA was carried out. There was a significant condition × group interaction in the mean RTs ($F(3, 158) = 2.86$, $p = 0.042$, $\eta p^2 = 0.05$), implying that the RT profiles across conditions were different between the two groups (Figure 7 and Table 4).

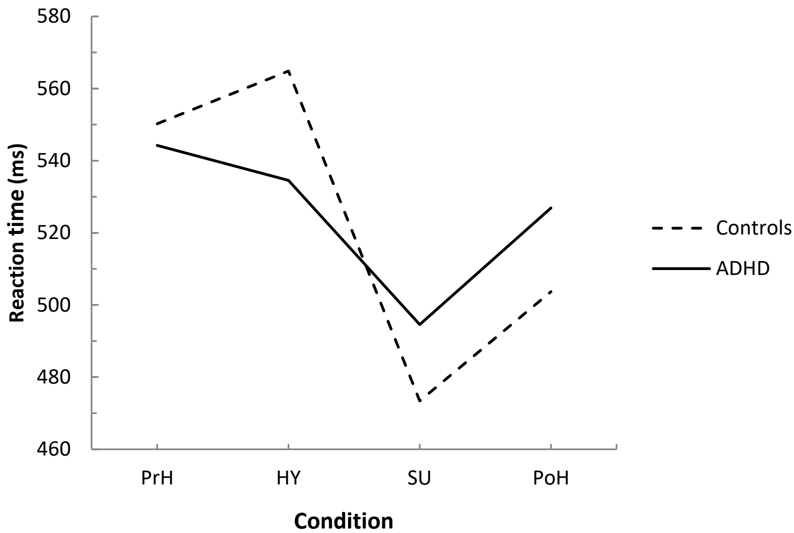

Figure 7 The mean RTs in the four experimental conditions for ADHD participants and healthy control participants. PrH = pre-hypnosis, HY = neutral hypnosis, SU = hypnotic suggestion, PoH = post-hypnosis.

Table 4. The mean RTs and their standard deviations in ADHD and control participants.

	ADHD (n = 27)				Controls (n = 31)			
	PrH	HY	SU	PoH	PrH	HY	SU	PoH
RT	544.2	534.5	494.6	526.9	550.2	564.9	473.4	503.7
(sd)	(112.8)	(162.2)	(119.7)	(121.3)	(87.5)	(105.3)	(83.6)	(85.0)

RT = reaction time; sd = standard deviation; PrH = pre-hypnosis; HY = neutral hypnosis; SU = hypnotic suggestion; PoH = post-hypnosis

These RT patterns were investigated in further detail using paired samples t-tests, separately for the ADHD and control groups. PrH was compared with HY, SU and PoH, and HY with SU.

In the ADHD group, the mean RTs did not differ between PrH and HY ($t(26) = 0.49$, $p = 1.00$, $d = 0.09$), whereas they did between HY and SU ($t(26) = 2.84$, $p = 0.034$, $d = 0.55$). The difference between PrH and SU approached statistical significance ($t(26) = 2.53$, $p = 0.071$, $d = 0.49$). The effect size, however, was moderate, the mean RTs differing by half a standard deviation. Noteworthy, the HY vs. SU difference was statistically significant, whereas the PrH vs. SU difference only approached significance. This was due to participants reacting differently when exposed to HY and SU conditions. When comparing SU with PrH, the RTs of eight participants increased and those of the others decreased. When comparing SU with HY, there was less variation in the pattern of differences, with less increase in RTs from HY to SU. This resulted in larger variance in the difference scores in the PrH vs. SU comparison, reflected in the higher p-value and the slightly smaller effect size than in the HY vs. SU comparison.

In the control group, the mean RTs did not differ between PrH and HY ($t(30) = -1.11$, $p = 1.00$, $d = 0.20$), whereas a statistically significant difference was observed between PrH and SU ($t(30) = 6.06$, $p < 0.001$, $d = 1.09$) and HY and SU ($t(30) = 5.61$, $p < 0.001$, $d = 1.01$). In both groups**,** the statistically significant difference between HY and SU indicates that the hypnotic suggestions resulted in faster RTs, over and above the effect of hypnotic induction. The differences between PrH and HY, even though non-significant, were unequal between the two groups: in the control group RTs became, on the average, slower whereas in the ADHD group they became faster (see Figure 7 and Table 4). There was also larger variation between the participants in HY than in the other conditions (see Table 4).

The two non-hypnotic conditions, PrH and PoH, were also compared. The difference between PrH and PoH was not significant in the ADHD group ($t(26) = 1.15$, $p = 1.00$, $d = 0.22$), but was significant in the control group ($t(30) = 3.30$, $p = 0.008$, $d = 0.59$). The gain score analysis showed that the PrH vs. PoH difference was not statistically significantly different across the groups (independent samples t-test, $t(56) = -1.41$, $p = 0.163$).

5.4 Study IV

Mean scores of the self-report measures for the hypnotherapy and CBT treatments are presented in Table 5.

To compare the hypnotherapy group with the CBT group during the follow-up, a two-way mixed design 3 × 2 rmANOVA was carried out (the scores at T2, T3 and T4 were included in the analysis, see also Table 5). No significant time × group interaction was found in BADDS total scale or in any of the BADDS subscales. The interaction approached significance in SCL-16 score of ADHD symptoms ($F(2,30) = 3.24$, $p = 0.053$, $\eta p^2 = 0.178$). There was a significant time × group interaction in SCL-90 total score of overall psychiatric symptoms ($F(2,30) = 4.10$, $p = 0.027$, $\eta p^2 = 0.215$) and in BDI-II score of the depression symptoms ($F(2,30) = 3.34$, $p = 0.049$, $\eta p^2 = 0.182$). In SCL-90 subscales, there was a significant time × group interaction in anxiety symptoms ($F(2,30) = 5.73$, $p = 0.008$, $\eta p^2 = 0.28$). No significant time × group interactions were found in any other SCL-90 subscales.

Table 5. Mean (standard deviation) scores for participants' self-ratings at T1 (before treatment), T2 (immediately after treatment), T3 (three months after treatment), and T4 (six months after treatment) with the time x group interactions in rmANOVAs for the follow-up period (the scores at T2, T3 and T4 were included in the analysis).

	Hypnotherapy (N = 8)				CBT (N = 9)				F(2,30) [a]	p-value
	T1	T2	T3	T4	T1	T2	T3	T4		
BADDS										
Activation	17.8	14.4	15.3	14.9	20.2	17.4	15.3	17.2	0.40	ns
	(5.3)	(6.5)	(6.8)	(6.0)	(2.2)	(4.7)	(3.9)	(3.5)		
Attention	18.9	16.6	14.6	16.0	21.8	18.1	15.7	18.1	0.08	ns
	(4.9)	(5.7)	(7.6)	(6.5)	(3.1)	(5.3)	(5.2)	(5.5)		
Effort	14.8	13.5	11.5	11.6	18.2	15.9	13.7	14.4	0.05	ns
	(5.5)	(4.9)	(6.0)	(6.2)	(4.5)	(4.6)	(6.0)	(4.7)		
Affect	9.3	7.5	7.9	7.4	11.4	9.8	8.9	11.3	1.96	ns
	(4.0)	(3.8)	(4.4)	(2.9)	(2.2)	(2.9)	(4.0)	(4.4)		
Memory	12.9	10.6	11.3	9.9	11.8	10.1	9.4	10.8	1.85	ns
	(4.1)	(2.5)	(2.9)	(3.7)	(4.4)	(5.1)	(3.6)	(4.5)		
Total	73.5	62.6	60.5	59.8	83.4	71.3	63.0	71.9	0.69	ns
	(17.0)	(17.7)	(21.3)	(19.9)	(12.8)	(19.7)	(18.7)	(18.4)		
SCL-16	28.1	20.4	18.5	16.3	30.3	25.1	24.9	29.6	3.24	0.053[c]
	(12.4)	(10.0)	(9.7)	(8.8)	(7.5)	(5.6)	(11.6)	(12.6)		
SCL-90	87.6	62.0	56.6	51.6	92.3	78.7	80.9	106.4	4.10	0.027
	(46.5)	(40.8)	(33.0)	(36.2)	(19.9)	(27.3)	(53.7)	(54.5)		
BDI-II	12.0	9.6	6.4	6.5	13.3	9.0	12.0	13.6	3.34	0.049
	(10.8)	(10.9)	(4.6)	(7.4)	(5.8)	(8.8)	(10.6)	(6.9)		
Q-LES-Q[b]	57.0	65.1	67.8	70.6	56.4	63.0	60.0	57.3	1.37	ns
	(17.4)	(13.8)	(12.4)	(16.3)	(8.8)	(14.1)	(14.2)	(9.6)		

NOTES: [a] two-way mixed design repeated-measures ANOVA, measures at T2, T3 and T4 included
[b] Quality of Life Enjoyment and Satisfaction Questionnaire general scale, higher scores indicate greater enjoyment or satisfaction
[c] approached significance
T1 = pre-treatment
T2 = post-treatment
T3 = three-month follow-up
T4 = six-month follow-up
BADDS = Brown Attention Deficit Disorder Scale
SCL = Symptom Check List
BDI = Beck Depression Inventory
ns = non-significant

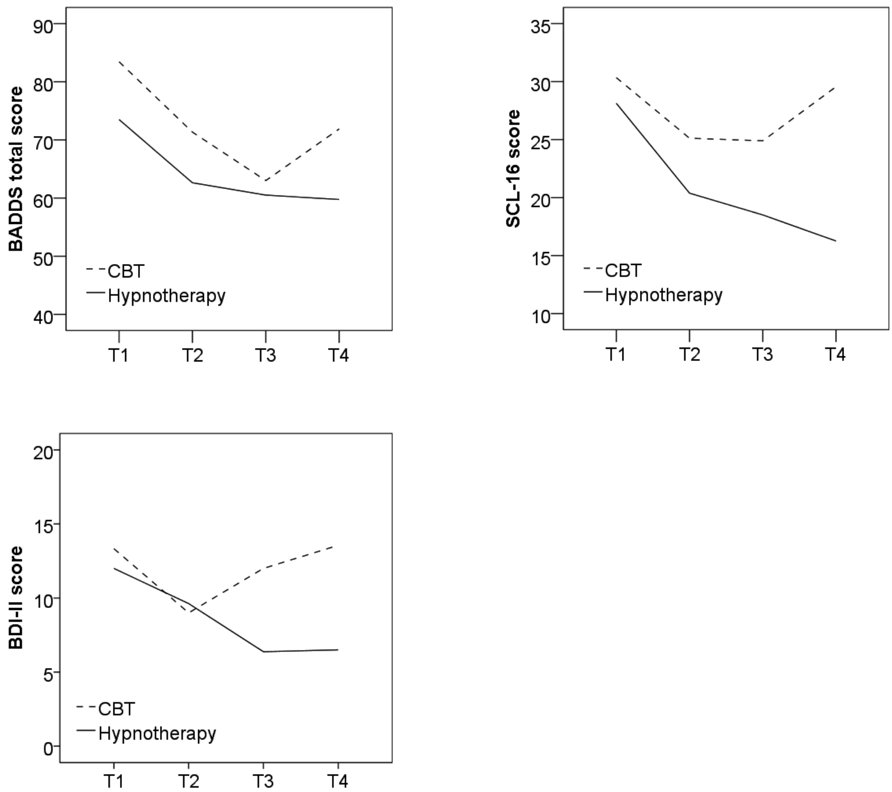

Figure 8 BADDS and SCL-16 scores for ADHD symptoms and BDI-II score for depression symptoms at T1 (before treatment), T2 (immediately after treatment), T3 (three months after treatment) and T4 (six months after treatment) for CBT (N=9) and hypnotherapy (N=8) groups.

To investigate the persistence of the benefits from the treatment during the follow-up, ADHD symptoms at the end of the treatment (T2) were compared with those at the end of the follow-up (T4) separately for both groups. In the hypnotherapy group, there was a decrease in ADHD symptoms in SCL-16 ($t(7) = 3.01$, $p = 0.020$, d = 1.06) and no change in BADDS total ($t(7) = 0.44$, $p > 0.05$). Thus, ADHD symptoms decreased or remained stable during the follow-up in the hypnotherapy group (see Figure 8). In the CBT group (Figure 8), ADHD symptoms of SCL-16 appeared to increase between T2 and T4 qualitatively, but the increase was not statistically significant ($t(8) = –1.41$, $p > 0.05$). In BADDS total scale, there was also no statistically significant change between T2 and T4 ($t(8) = –0.11$, $p > 0.05$). The mean value of the BADDS total scale at T4 was about the same level as at T2, despite the increasing trend of symptoms from T3 (see Figure 8). In summary, the treatment outcome during the follow-up, as measured with ADHD symptoms, appears more stable in the hypnotherapy group than in the CBT group.

When comparing BDI-II scores between T2 and T4 separately for both groups with a paired *t*-test, there was a statistically almost significant decrease in BDI-II scores in the hypnotherapy group ($t(7) = 2.16$, $p = 0.067$, $d = 0.76$). In the CBT group, on the contrary, BDI-II scores seemed to return to the pretreatment level (Figure 8), but the increase in BDI-II scores from T2 to T4 was not statistically significant.

According to the CGI ratings by independent evaluators, three of the eight participants in the hypnotherapy group improved (from T2 to T4) during the follow-up, and none declined. In the CBT group, in turn, one of the nine participants improved, and two declined. However, Fisher's exact test revealed that the group differences were not significant.

In the hypnotherapy group, the symptoms, in general, tended to decrease or remain stable during the six-month follow-up (as also seen in Table 5). In the CBT group, there was more variation in the treatment outcome during the follow-up. Qualitatively, the symptoms seemed to increase during the second three-month period of the follow-up as compared to the preceding evaluation (see Table 5). In summary, the treatment outcome during follow-up, as measured with ADHD and its typical comorbid symptoms, appears to be more stable in the hypnotherapy treatment than in CBT.

6 Discussion

The present thesis examined hypnosis and its effects on attention and ADHD from three different perspectives: brain functions (spectral power densities and ERPs), behavioral performance and clinical applications.

6.1 Main findings of the thesis

The first general aim was to examine whether the EEG activity in hypnosis differs from the wake state in highly hypnotizable participants. No evidence was found that hypnosis is differing from the normal wake state from the neurophysiological point of view, as revealed by the spectral power density in theta or any other EEG frequency band. However, a trend toward a decreased gamma power in hypnosis-related conditions was observed, but it was statistically significant only between SU and PoH conditions.

The second general aim was to examine the effects of hypnotic suggestions on two distinct stages of auditory attention information processing, namely involuntary pre-attentive change detection (as indicated by MMN) and sustained attentional performance in a CPT task. Neither hypnotic suggestions given to alter the perception of the tones nor the hypnotic state *per se* had any effect on the MMN amplitude. In turn, top-down influences of hypnotic suggestions for speed and accuracy had a clear effect on RTs in the CPT, improving performance in healthy control participants.

The third aim was to find out whether hypnosis can be applied for treating adults with ADHD. The questions studied included whether hypnotherapy can be used to relieve their ADHD symptoms in the long term and whether hypnotic suggestions can be used to improve their sustained attentional performance. Hypnosis, hypnotic suggestions and hypnotherapy were also found to be a suitable method in the ADHD adult population since the hypnotic suggestions improved their RTs in a CPT task. Moreover, a pilot-type clinical follow-up study showed that during the six-month follow-up, the treatment benefits remained better after the hypnotherapy treatment than after the CBT treatment.

6.2 Effects of hypnosis on spectral power density

The results of the present thesis do not support previous assumptions (Sabourin et al., 1990; Williams & Gruzelier, 2001; Jensen et al., 2015), according to which hypnosis differs neurophysiologically (as indicated by EEG oscillations) from the normal wake state. Thus, an increase in theta power or changes in any other EEG band power cannot be used as a straightforward marker of a hypnotic state. In two previous studies (Sabourin et al., 1990; Williams & Gruzelier, 2001) and in a review (Jensen et al., 2015), which based its conclusions mainly on those two studies, it has been proposed that the elevated theta power in particular characterizes hypnosis in highly hypnotizable individuals. It is noteworthy that two other studies (Jamieson & Burgess, 2014; White et al., 2008) have revealed results consistent with the conclusions of the present thesis, as they found no hypnosis-related differences in any EEG band. Terhune et al. (2011a) found an alpha2 power increase during hypnosis, but no results for any other EEG bands were reported.

The strongest support for the elevated theta power in hypnosis came from the study by Sabourin et al. (1990), with a sample size of 12 highly hypnotizable participants. However, they included only the very highly hypnotizable participants in their study. In addition, the slight procedural differences across studies should be noted. Hypnotic induction used in the present thesis and in the previous studies (Sabourin et al., 1990; Williams & Gruzelier, 2001) included similar parts: eye fixation, closing of the eyes, relaxation, and deepening of hypnosis. However, Sabourin et al. (1990) used tape-recorded induction followed by hypnosis-deepening suggestions which were, unfortunately, not described in detail. Williams and Gruzelier (2001) used longer counting to deepen hypnosis and then proceeded to give further deepening suggestions via guided imagery. Also, their subjects' eyes were closed during the EEG measurement. Hypnotizability and other individual differences, which may be related to the differences in the results between the studies, will be further discussed in Chapter 6.5. In the present thesis, no statistically significant theta-band effects were found and the effect sizes in the theta bands were small. Figure 3 shows that the possible changes in the mean power values in the theta bands are hardly visible over the conditions. Thus, it is unlikely that adding even a substantial number of participants to the present sample would have changed the results.

A statistically significant reduction in the gamma power between the SU and the PoH conditions was found (but, contrary to expectations, not between SU and PrH). Additionally, the difference between HY and PoH approached statistical significance. The trend was not so clear between PrH and HY (see Figure 4). These are the two most important conditions to be compared when investigating whether hypnosis differs from the normal wake state since it is known that participants in post-hypnosis may not be in a similar alert state of consciousness as in pre-hypnosis (Fingelkurts, Fingelkurts, Kallio, & Revonsuo, 2007b; Williams & Gruzelier, 2001). The observed tendency for the reduction of gamma power in hypnosis may be related to a reduced peripheral awareness, which typically characterizes the hypnotic state (for the characterization, see, e.g., the APA definition of hypnosis in Chapter 2.3.1, and also the conclusions in Vanhaudenhuyse and colleagues' (2014) review). The participants in Study I were keeping their eyes open and watching a video during the EEG experiment. One may speculate whether a kind of narrowing of the peripheral sensory input may have caused the tendency toward gamma-band power reduction.

Higher-frequency oscillations typically reflect more regional brain activity and they summate less well on the scalp level (Jensen et al., 2015). Consequently, the brain activity in the fast EEG bands is probably more condition- and suggestion-specific, and testing hypotheses related to them is generally more challenging than those related to lower frequencies (Jensen et al., 2015). Other types of the experiment (e.g., the experiment with eyes closed or different suggestions) may have resulted in different patterns of the higher frequency oscillation.

6.3 Effects of hypnosis and hypnotic suggestions on two stages of auditory information processing

6.3.1 Auditory pre-attentive information processing

No evidence was obtained that the brain's non-voluntary, pre-attentive change-detection mechanisms, as reflected by MMN, could be influenced by hypnotic suggestions. The suggestions were aimed to alter the tone perception (i.e., that all the tones will sound exactly similar in pitch). Only one multi-subject study (Facco et al., 2014) has earlier examined this issue. The study reported that the MMN was diminished due to hypnotic suggestions in highly hypnotizable participants. Their suggestions differed from those used in the present study and their smaller sample of high-hypnotizables (five) may have consisted mainly of subjects who were experienced with hypnosis, since the authors used a posthypnotic command to induce hypnosis and hypnotic amusia.

The experimental setup and stimulus parameters of Study II were designed to minimize the possibility of MMN being contaminated by other, partially simultaneous deviance-related ERP components (e.g., N1, N2b) or resting-state alpha band waves. Such factors may have been possible shortcomings in previous hypnosis MMN studies. Facco et al. (2014), for instance, used duration deviants to elicit MMN, their deviant stimuli being longer in duration than the standard stimuli. Consequently, in their study, there is a possibility that the MMN was partly contaminated by N1, as longer-duration stimuli typically activate the N1 generator more strongly than short stimuli (see, e.g., Kujala et al., 2007). Moreover, in their non-highly hypnotizable group ERPs, an effect of hypnosis also appears to be present, albeit at a longer latency (230–280 ms) than in the highly hypnotizable group. Whether this effect reflects a delayed MMN or a possible contribution of the attention-related N2b component (Kujala et al., 2007) is difficult to determine, as, unfortunately, the authors did not report what their subjects were doing during the conditions (e.g., whether their attention was directed to the sounds or to some other task) or how they were instructed to listen to the sounds (for further discussion on these interpretational difficulties, see Hiltunen et al., 2019).

Previous studies have reported neutral hypnosis increasing the MMN amplitude (Jamieson et al., 2005; Kallio et al., 1999). In this thesis, no statistically significant evidence for the effect of neutral hypnosis on the MMN amplitude was obtained. If anything, the possible trend was in the opposite direction than in the earlier studies. Kallio et al. (1999) used a single hypnotic virtuoso as their subject, and the possible factors explaining the different results might be related to hypnotizability and individual differences (see chapter 6.5 for further discussion). Jamieson and colleagues' (2005) study differed from Study II in their stimulus type (duration deviant), task (watching an illusory figure and pressing a button when experiencing reversal appearance of the figure) and statistical analysis (planned polynomial contrasts). The authors made a note about their analysis method that their hypothesized patterns may be significant even when no pair-wise comparison between the conditions reaches significance. In Study II, standard ANOVA procedures, commonly used in MMN studies, were applied.

On the basis of the present results, MMN might reflect, after all, the operation of such low-level, "hard-wired" brain mechanisms that cannot be influenced by top-down processes, induced by the hypnotic suggestions. Interestingly, there is evidence that the direction of very strongly focused attention can modulate the MMN amplitude (Sussman, 2007; Woldorff et al., 1998), but this phenomenon has been found only in more demanding, dichotic-listening paradigms but not in simple two-tone oddball paradigms. Thus, hypnosis itself, although typically involving focused attention, does not seem to be able to cause this kind of attention-related MMN modulation. A further alternative is that some differences in the highly hypnotizable individuals used in the various hypnosis-MMN studies might explain their inconsistent results. The possible inter-individual factors are further discussed in Chapter 6.5.

The absence of hypnotic-suggestion effects on the preattentive processing levels reflected by MMN cannot, however, be necessarily generalized to the later stages of the auditory information processing. One interesting question for future studies could be whether hypnotic suggestions can be used to inhibit auditory distraction, for instance, involuntary attention switching triggered by salient deviant stimuli. This bottom-up type of involuntary attention triggering is reflected in the P3a component of the ERP (Escera, Alho, Winkler, & Näätänen, 1998; Escera & Corral, 2007). The hypnotic suggestions might be able to influence this processing stage as, for example, the suggestions used in the hypnotherapy treatment have been observed to reduce ADHD symptomology (Virta et al., 2010a). In ADHD, the distractions due to too sensitive bottom-up attention triggering are a common problem. Consequently, further

MMN and P3a experiments, as well as studies investigating even later processing stages, are required to resolve these issues.

6.3.2 Voluntary auditory information processing

The second general aim also focused on the effects of hypnosis and hypnotic suggestions on the voluntary auditory information processing in a task requiring sustained attention. In Study III, hypnotic suggestions for speed and accuracy had a clear influence on behavioral performance in a voluntary attentional task (CPT).

There was a statistically significant decrease in the RTs from HY to SU in the healthy control group participants. Additionally, the RT difference between PrH and SU was statistically significant. Although the RT changes from PrH to HY were not statistically significant in control participants, there was a tendency for the RTs to increase in HY. This is in line with a previous study (Kallio et al., 2001) where hypnosis slightly slowed down the RTs.

There are no previous studies about the influence of hypnotic suggestions on the CPT task. However, the results of Study III are in line with previous studies with other kinds of attentional tasks. The reduction or elimination of the Stroop effect after posthypnotic suggestions has been shown in several studies, in both high (MacLeod & Sheehan, 2003; Raz et al., 2005; Raz et al., 2006; Raz et al., 2002; Zahedi et al., 2017) and low hypnotizable participants (Raz & Campbell, 2011). Also, the Flanker compatibility effect (Iani et al., 2006) and the Simon effect (Iani et al., 2009) have been eliminated or reduced with posthypnotic suggestions in highly hypnotizable participants. In all these tasks, including different kinds of conflict conditions, suggestions have been proposed to inhibit automatic processes.

Interestingly, by using a semantic version of the Stroop test, Augustinova and Ferrand (2012) did not find any effect with the suggestions in highly hypnotizable individuals. In the semantic version of the Stroop test, standard incongruent trials (e.g., the word "blue" displayed in green) were substituted for the presentation of words that were simply associated with an incongruent color (e.g., "sky" displayed in green). The authors argued that semantic activation could not occur without reading and concluded that the suggestions simply reduced non-semantic task-relevant response competition, but did not de-automatize and inhibit the automatized reading in their study and the earlier Stroop studies. This example shows that it is not necessarily clear how and on which level the top-down influences of hypnotic or posthypnotic suggestions are implemented.

In the healthy control participants, the hypnotic suggestions had a clear effect on RTs in the CPT task, and the effect also nearly returned to the "wake state" pre-hypnosis baseline performance after the termination of hypnosis and the suggestions. On the basis of the present CPT experiment, it cannot be inferred in which brain areas or at which stage of information processing the suggestions exerted their performance-improving top-down effects: Is it at the perceptual, attentional, decision-making or motor-response stage, or all stages from perception to the reaction? In Study III, the hypnotic suggestions included suggestions for improving perception, attention, reaction, and motor responses. Consequently, improvements in all those stages may have been involved. The cognitive and perceptual stages at which suggestions implement their effects have received only a little attention in hypnosis research (Terhune et al., 2017). In future studies, more focused suggestions may be used to obtain more precise information about this issue.

6.4 Applicability of hypnosis for treating adults with ADHD

6.4.1 Hypnotherapy follow-up in adults with ADHD

The first part of the third general aim was to investigate whether hypnotherapy can be used in adults with ADHD to relieve their ADHD symptoms. The results indicated that the benefits of the short individual hypnotherapy treatment remained during the six-month follow-up, and unexpectedly, the treatment outcome was even more stable than with the corresponding short CBT treatment. The treatment outcomes differed statistically in general psychological well-being, anxiety and depression, and approached significance in a scale of ADHD symptoms, indicating a better long-term outcome for hypnotherapy. There are no earlier studies of hypnotherapy interventions for adults with ADHD, except the afore-mentioned study (Virta et al., 2010a) whose follow-up data were analyzed in this thesis. Thus, comparison with this patient group to earlier hypnotherapy studies cannot be done.

In previous individual CBT follow-ups, a tendency for a slight increase in the ADHD symptoms has typically been observed in follow-ups longer than three months (12-month, Safren et al., 2010; 9-month, Corbisiero et al., 2018). Thus, the follow-up outcome of the CBT treatment in Study IV seems to be well in line with earlier CBT studies, since a slight increase in the mean scores of the symptoms toward the end of the follow-up was exhibited. It should be noted that the CBT benefits nevertheless remained at follow-up, and the trend toward the symptom increase was not statistically significant. However, when compared to the outcome of the hypnotherapy follow-up, the difference in the outcomes reached or approached statistical significance.

Hypnotherapy and CBT treatment groups did not differ statistically from each other before the treatment. The outcomes of the two treatments did not differ at the end of the treatment period either. Thus, the difference in the long-term efficiency of the treatments somehow emerged during the follow-up. When such pilot types of treatments are used as in Study IV with quite a limited number of participants, the role of random fluctuations and the contributions of a few exceptional individuals may have more influence on the results. As one example, the qualitative differences in comorbidity between the participants may have influenced the long-term outcome, especially in the short ten-session interventions used: in the hypnotherapy group, four participants had a comorbid diagnosis, whereas in the CBT group seven had a comorbid diagnosis (of which six were depression).

The hypnosis-related factors underlying the better long-term stability of the hypnotherapy outcome can also be speculated on. The differences between the long-term outcomes of the two treatments were statistically significant in overall well-being, anxiety and depression, and approached significance in ADHD symptoms (in one of the two scales). Due to the small number of studies in the field of hypnotherapy, a straightforward answer cannot be easily found from the literature. In Kirsch and colleagues' (1995) meta-analysis, CBT was compared with the same therapy supplemented by hypnosis. Follow-up data were only available for the treatment of obesity. When hypnosis was used, the largest weight loss was observed six months after the treatment and the weight remained at a reduced level in a two-year follow-up. In the CBT treatment without hypnosis, the weight tended to slightly start increasing during the follow-up. Kirsch et al. (1995) speculated that the advantages of adding the hypnosis to CBT treatment may increase over time regardless of the target disorder. On the other hand, a follow-up study by Bryant et al. (2006), treating acute stress disorder, compared CBT and CBT combined with hypnosis. Although the CBT with hypnosis led to greater reductions than the CBT alone in re-experiencing symptoms at the post-treatment, this difference was not evident at either the six-month or three-year follow-up assessments.

The ADHD treatments in this thesis were mainly designed for teaching new skills and coping strategies and addressing secondary problems of ADHD, such as negative thoughts and beliefs. In hypnotherapy, teaching new skills or strategies or addressing secondary problems may not be so explicitly perceptible to the participant as in CBT, since such actions (e.g., relaxation, motivation to change, initiation of the actions, self-esteem, anger management) during the hypnotherapy are in the forms of suggestion and imagery. Hypnosis itself may exercise the brain's executive and attentional functions by focusing or narrowing the scope of attention. Thus, hypnotherapy may serve as a rehabilitation exercise for the brain areas which are impaired in ADHD. Hypnosis has been observed to influence the anterior cingulate cortex (Kihlstrom, 2013), a brain area crucial for executive functioning, inhibitory control monitoring, target detection and error processing (Schneider, Retz, Coogan, Thome, & Rosler, 2006), all functions in which adults with ADHD typically have problems. Hypnosis has also been observed to boost striatum-dependent sequence learning (Nemeth, Janacsek, Polner, & Kovacs, 2013). The authors speculated that during hypnosis, the participants shifted from relying on frontal lobe related attentional processes to the use of automatic non-conscious procedural-based mechanisms, resulting in enhanced sequence learning. If such a shift in the learning can take place during hypnosis, one may also speculate whether a similar boost of learning could also happen in the participant's imagery during a therapeutic hypnotic session. Via such mechanisms, the learning of the new "skills" and positive thoughts and beliefs may be strengthened more efficiently in hypnotherapy than in CBT.

Alladin (2012b) has proposed that hypnotherapy is concerned more with insight and non-conscious reframing, while CBT concentrates on cognitive restructuring. In Casiglia, Tikhonoff, and Facco's (2016) review of their research group results, influences of hypnosis and suggestions on the brain's non-conscious processes were reported from many different types of experimental settings, including Stroop-effect and analgesia studies as well as the afore-discussed MMN study (Facco et al., 2014). Thus, with hypnotherapy and suggestions, it may be possible to exert broader influence on different brain functions and regions than with traditional cognitive methods.

Although a relaxation treatment with psychoeducational support has not been found to be as effective as CBT in treating adults with ADHD (Safren et al., 2010), the use of hypnosis, with its deep relaxation experience, may have a direct impact on the hyperactivity and impulsivity symptoms in ADHD. Such an experience, happening perhaps for the first time in the person's life, may be an empowering and unforgettable experience (Alladin & Alibhai, 2007) and give rise to a new sense of hope (Alladin, 2012a). The attitude of hope has been proposed to be one of the main goals to be taught in hypnotherapy (Huynh, Vandvik, & Diseth, 2008). In psychological treatments, in addition to the alliance (Fluckiger, Del Re, Wampold, & Horvath, 2018; Horvath & Symonds, 1991) and empathy (Elliott, Bohart, Watson, & Murphy, 2018), the expectations of the patient have also been recognized as central influencing factors (Greenberg, Constantino, & Bruce, 2006; Mondloch, Cole, & Frank, 2001). After the treatments, the hypnotherapy participants of the present thesis, as compared to CBT participants, had a stronger belief that things in their life are going to get better in the future (for more details, see the original publication of Hiltunen et al., 2014). Keeping in mind that expectations are commonly theorized to be an important causal determinant of the placebo effect (e.g., Steward-Williams & Podd, 2004), there may have been also a stronger placebo effect in the hypnotherapy participants than in the CBT participants during the follow-up.

An interesting study with children, employing treatment resembling neurofeedback with a sham MRI scanner, revealed that even with full disclosure of the placebo procedure, the suggestion alone can reduce ADHD symptoms (Thibault, Veissiere, Olson, & Raz, 2018). The participants were told that the "brain machine" was inactive, and it is used just as a suggestion that would "help their brain to heal itself". At follow-ups, the parents of the participants reported improvements in eight out of the nine ADHD children. There was no control group in this study.

Another study specifically tested the placebo effect by using sham medication in adults with ADHD (Ben-Sheetrit et al., 2020). Pre–post changes in placebo-treated adults were significant when measured with two ADHD symptom scales. Less than half of the participants had a persisting placebo response which began early in the treatment, and almost half of the participants had a varying, inconsistent placebo response. The authors speculated that unintended therapeutic interactions with the clinicians who collected the data for the study might enhance the placebo response with time. Participants may be expecting a response and believe that the investigators expect it too. As a consequence, the benefits of the treatment may have been overestimated in the final assessment (Ben-Sheetrit et al., 2020). In Study IV, this effect, if present, should have been similar in the CPT and hypnotherapy groups since the follow-up assessments were carried out in the same way in both groups.

Both CPT and hypnotherapy treatments were semi-structured, and treatment manuals were followed. The strict use of the manual does not necessarily result in a better outcome (Ahn & Wampold, 2001), since the flexibility of the therapist has been considered as a more important factor (Norcross & Wampold, 2011). In the present thesis, the procedures of both treatments allowed the therapist flexibility and the slavish adherence to the manual (which may cause ruptures to the alliance and, consequently, poorer therapy outcomes; see, e.g., Ahn & Wampold, 2001) was avoided. Since both the CPT and hypnotherapy treatments had equal outcomes at the end of the treatment, it is unlikely that such treatment- or therapist-related aspects contributed to the differences during the follow-up. In a summary, more research on the long-term efficacy of hypnotherapy in ADHD adults is warranted to verify and confirm the speculations above.

6.4.2 Hypnotic suggestions in improving attentional performance

In the ADHD group, hypnotic suggestions for speed and accuracy had a clear influence on RTs in the voluntary auditory attentional task. There was a statistically significant decrease in RTs from HY to SU. The difference between PrH and SU approached significance with a moderate effect size. There are no previous studies on the influence of hypnotic suggestions on CPT in ADHD adults. Although CPT has been commonly used in studies with ADHD adults, due to different procedures and stimuli, their results are not easy to compare with those obtained with the short auditory version of the CPT in the present thesis.

The statistically significant group × test condition interaction indicated that the RT profiles across the conditions were different between the two groups (see Figure 7). In the ADHD group, RTs were the longest in PrH, followed by a decrease in both HY and SU. In the control group, RTs were the longest in HY, followed by a substantial reduction in SU. Although the RT changes from PrH to HY were not statistically significant in the ADHD group (nor in the control group), there was a tendency for the RTs in the control group to increase in HY and those in the ADHD group to slightly decrease. This tendency for different patterns is interesting. One may speculate that because the induction includes focusing on attention, its impact is different on ADHD participants because they have attention deficits. Alternatively, the hypnosis-related relaxation effects on attention and RTs might, in general, be different between control and ADHD participants. There are no previous studies on the impact of hypnosis on attentional performance in ADHD adults. More research is thus needed.

In the CPT task, the RTs of the two groups did not differ in the pre-hypnosis baseline measurements. This is in line with most of the previous studies (Balint et al., 2009; Hervey et al., 2004; Raz et al., 2014), although in some studies the ADHD participants have been slower (Advokat et al., 2007; Gualtieri & Johnson, 2006) or slightly faster (Epstein et al., 1998) than the controls. In Study III, the influence of the suggestions on RTs was slightly weaker in the ADHD group (reduction from HY to SU 7.5%) than in controls (16.2%). When compared to the pre-hypnosis baseline, the difference between the groups was smaller (reductions from PrH to SU for ADHD and control groups were 9.1% and 14.0%, respectively). Consequently, there was no large difference between the groups, but it is possible that the influence of suggestions on RTs was slightly larger in the control participants.

Some of the results in the ADHD group seem a bit counterintuitive when examining the profiles in Figure 7. For example, the HY vs. SU difference was clearly statistically significant, with the PrH vs. SU difference only approaching significance. This is due to the fact that the change patterns differed between the participants in the ADHD group; 19 (70.4%) of the ADHD participants performed faster in SU than in PrH but 8 (29.6%) performed slower. No reason was found for this. For instance, the severity of the symptoms did not explain the phenomenon. In the control group, in turn, three (9.6%) participants performed slower in SU than in PrH. As there seemed to be more inter-individual variability in the ADHD group, one might speculate that, in general, there may be more individuals in the ADHD adult population to whom the use of the hypnotic suggestions does not necessarily provide the intended improvement in attentional performance.

6.4.3 Safety considerations in using hypnosis

Thus far, none of the relatively few studies with ADHD adults as participants has reported any adverse effects due to hypnosis/hypnotherapy. In a review of all hypnosis-related clinical trials (Bollinger, 2018), the reported rate of adverse events likely attributable to hypnosis was 0%, and the rate of other adverse events 0.47%. In those trials, various diseases were treated with hypnosis. A meta-analysis of the efficacy, tolerability and safety of hypnosis in adult irritable bowel syndrome concluded that hypnosis was safe and provided long-term adequate symptom relief in 54% of the patients refractory to conventional therapy (Schaefert et al., 2014). One (0.4%) of 238 patients in the hypnosis group dropped out due to an adverse event (panic attack). When a safe and reasonable use of hypnosis is not secured, negative consequences may be more frequent. For instance, in a study of 22 stage hypnosis participants, 36% reported confusion and 9.1% reported feeling frightened as a result of hypnosis (Crawford, Kitner-Triolo, Clarke, & Olesko, 1992). In the studies of the present thesis, earlier psychosis or current severe depression were used as exclusion criteria to minimize risk for adverse events. On the other hand, hypnosis has also been applied for treating depression (Alladin, 2007, 2012a) and psychotic patients (Baker, 1983; Scagnellijobsis, 1982). As a summary for the third general aim, the results of Studies III–IV in the present thesis and the aforementioned safety considerations propose that hypnosis and hypnotherapy can be applied in treating ADHD adults.

6.5 The effects of hypnotizability and other individual differences on the results

The hypnotizability of a person is one trait that manifests in inter-individual differences. The participants in Studies I and II were highly hypnotizable individuals and the participants in Studies III and IV were low, medium and highly hypnotizable individuals.

The effect of hypnotizability on the outcomes of the studies is not as straightforward a factor as might be expected, and the realization of hypnotic suggestions does not only depend on hypnotizability. For instance, attitudes and expectancies are very important factors, although they have been assessed much less frequently than hypnotizability in hypnosis studies (Schoenberger, 2000). Even highly hypnotizable individuals are not a homogenous group (Terhune, 2015). For example, one subtype of them has been found to be more responsive to positive and negative hallucination suggestions and to experience enhanced involuntariness, whereas another subtype has displayed superior visual object imagery (Terhune, Cardena, & Lindgren, 2011b). Terhune (2015) further studied a sample of individuals in the upper range of hypnotizability and analyzed their response patterns in a diverse battery of difficult hypnotic suggestions. He was able to classify the individuals on the basis of a four-class model. One class was comprised of very highly hypnotizable participants (virtuosos), two classes included highly hypnotizable participants who were more responsive to either inhibitory cognitive suggestions or posthypnotic amnesia suggestions, and the fourth class consisted primarily of medium hypnotizable participants. Individuals, irrespective of the hypnotizability, may also use different strategies to implement suggestions (Oakley & Halligan, 2013), and the expectations toward hypnosis and hypnotic suggestions may influence how the suggestions are realized: some may expect the suggestions to be realized automatically, while others may give their imagination free rein in order to realize the suggestions. With quite simple, but still rather demanding, perception-altering suggestions as those used in Studies I–II, it is likely that the highly hypnotizable participants may differ in how vividly the suggestions are realized. The realization of the suggestions was difficult to clarify in the post-experiment interviews since the participants were instructed that there is no need to pay any attention to the sounds in the environment during the experiment. For future hypnosis studies, Terhune et al. (2017) have suggested that advancing the measurement of hypnotic suggestibility may be necessary to better understand the neurocognitive profile of highly hypnotizable individuals.

Additionally, the depth of hypnosis, which is not possible to measure objectively, may vary from one situation to another. For instance, opening the eyes during hypnosis (which was required in Studies I and II) may have influenced the depth of hypnosis. Some participants reported afterward that they felt they had been in deeper hypnosis in the group session for hypnotizability measurement than during the actual EEG recordings. However, the participants' subjectively evaluated depth values and their interview comments indicate that the participants had experienced being under hypnosis during the EEG experiment, although there was still some space for deepening of hypnosis.

In Study III, the effect of hypnotic suggestions on RTs compared to that of neutral hypnosis did not statistically differ between the low and high hypnotizables. Furthermore, there was no significant correlation between hypnotizability and RT improvements over all participants, although there was a trend for the highly hypnotizables to improve their RTs more than the low ones. In the control group, there was a moderate correlation between hypnotizability and the improvement of RTs. The reduction of the Stroop effect (MacLeod & Sheehan, 2003; Rax et al., 2005; Raz et al., 2006; Raz et al., 2002; Zahedi et al., 2017), the Flanker compatibility effect (Iani et al., 2006) and the Simon effect (Iani et al., 2009) by hypnotic suggestions have been demonstrated only in high but not in low hypnotizable subjects. As an exception, the reduction of the Stroop effect was also found, although to a lesser extent, in low hypnotizables by Raz and Campbell (2011). Consequently, in these types of tasks, hypnotizability clearly affects the results. The CPT task, however, differs from them by not including any conflict conditions where the successful realization of the suggestions may depend more on the hypnotizability of the participant.

The hypnotizability of ADHD adults may well be within the same range as that of the healthy controls. In Study III, the mean susceptibility measured with HGSHS:A was, in both groups (ADHD: 7.15, controls: 6.42), within the range of Finnish norms (7.26; Kallio & Ihamuotila, 1999), even though the controls scored slightly lower. In Study IV, the ADHD participants in the hypnotherapy scored (5.9) slightly lower than the participants in the Finnish norms. Interestingly, Lotan, Bonne, and Abramowitz (2015) found that ADHD medication with methylphenidate enhanced hypnotizability in adults with ADHD. With the medication, the mean SHSS:C score was observed to increase by 2.27 points compared to baseline, and all ADHD participants who had initially been low scorers received medium or high hypnotizability scores during methylphenidate treatment. Thus, the medication may help to focus on attention. During the CPT experiment of the present thesis, six participants normally having ADHD medication did not use their medication, and ten of the ADHD participants were non-medicated. The effects of the hypnotic suggestions on the performance of the ADHD group might have been stronger if they had used ADHD medication.

In Study IV, the hypnotherapy participants' hypnotizability scores ranged from 2 to 10, but the small sample size in the follow-up did not allow for a more precise comparison between different hypnotizability groups. Most of the participants in the hypnotherapy group were medium hypnotizables and they preserved their treatment benefits, as the outcome was more stable than in the CBT group. In a one-year follow-up study on cognitive hypnotherapy for depression (Alladin & Alibhai, 2007), the moderately to highly hypnotizable participants' depression scores improved significantly more than those of the low hypnotizable participants. Their participants had also anxiety symptoms, and there was no correlation between the hypnotizability and anxiety scores at the termination of treatment. The authors concluded that the majority of the participants, irrespective of their level of hypnotizability, benefited from the management of the anxiety. That the correlation between hypnotizability and clinical improvement was only moderate was, according to the authors, a finding consistent with the earlier literature. Lynn, Kirsch, Barabasz, Cardena, and Patterson (2000) have proposed that this is due to the fact that the most typical hypnotherapy interventions rely on relatively easy suggestions that require little hypnotic or imaginative ability to be realized. It should, however, be noted that in the hypnotherapy interventions, like in Study IV, the hypnotic session is not just a sequence of hypnotic suggestions given by the therapist. It also includes, for example, the use of imagery and therapeutic interactions between the therapist and the client who is in the hypnotic state.

6.6 Methodological considerations

The present thesis applied diverse methods: EEG was used for measuring the brain activity in Studies I and II, behavioral performance was measured in Study III, and clinical evaluations in the form of self-reports and independent evaluations were used in Study IV. This methodological diversity is one strength of the thesis.

The afore-discussed “null” findings of Studies I–II (no effect of hypnosis on theta nor MMN) were partially contradictory to previous literature. It is a well-known problem that researchers in psychology too often report only findings supporting their hypotheses while opposite and null findings are left unpublished (Ferguson & Heene, 2012). According to Fanelli (2010), this publication bias is approximately two times higher in social and behavioral sciences than, for instance, in physical sciences. It may contribute to the “replication crisis”, which has been extensively debated in recent years in psychology and cognitive neurosciences (Huber, Potter, & Huszar, 2019; Maxwell, Lau, & Howard, 2015; Shrout & Rodgers, 2018). Ferguson and Heene (2012) further argued that the publication bias can reduce the capability of psychological science to maintain proper mechanisms for theory falsification, and may result in the promulgation of numerous theories that may be ideologically popular but have too little empirical support behind them, due to lack of replications. From this point of view, Studies I–II have, for their part, contributed to remedying this transparency problem, as they also include results which do not provide support for the prevailing theories or confirm findings of earlier studies. However, one limitation in interpreting their results is the rather small sample size. In future studies, larger sample sizes should be used. Furthermore, Bayesian statistics could be used to better demonstrate whether the data is consistent with the null hypothesis or not.

Study II focused on highly hypnotizable participants, where the possible effect of hypnosis on MMN was supposed to be strongest. It was also designed to avoid certain shortcomings and interpretational problems of previous hypnosis and MMN studies, by using more “standard” MMN methodology in the experiment and analysis. Studies III and IV investigated the use of hypnosis in a new type of application, where no previous research literature was available.

The present studies also have some common and some study-specific limitations that should be considered. In all studies, hypnotizability was measured by using a group test (HGSHS:A). An individual assessment (e.g., SHSS:C), in addition to a group variant, might have provided a more accurate estimate of each participant’s hypnotizability. HGSHS:A was adopted as it is commonly used and provided a reasonably good, time-saving compromise for the estimation of hypnotizability.

Studies I–III were lacking the counterbalancing of the different conditions. However, a perfect counterbalancing was impossible in the present multi-condition hypnosis experiments: the position of the pre-hypnosis and post-hypnosis conditions is, for obvious reasons, fixed and only the positions of the hypnosis-related conditions could, in principle, be counterbalanced. With only two of them, the natural order is to have neutral hypnosis first and then to continue to the suggestion condition, just by giving the hypnotic suggestions. Pre-hypnosis and post-hypnosis conditions are known to slightly differ from each other, since the participants may not be in a similar alert state of consciousness after hypnosis as they were before it (Fingelkurts et al., 2007b; Williams & Gruzelier, 2001). In future studies, fatigue and practice effects on the successive conditions could also be controlled for, for instance, by adding a control group which executes all four conditions in a waking state (i.e., without hypnosis and suggestions).

In Study I, the power densities were estimated from the EEG data collected for Study II. Consequently, the experimental design was not fully optimal for the purposes of Study I, due to the continuous auditory background stimulation needed for MMN elicitation. The constant stimulation might have its own effects on the brain oscillations. However, as the auditory stimulation was exactly similar in all four conditions, the comparison of the oscillatory activity between the conditions was considered unproblematic.

Recent recommendations for future hypnosis studies have emphasized the use of designs that could more clearly delineate the roles of inductions and specific suggestions as well as the need to also include participants who score in the middle range of hypnotic suggestibility (Jensen et al., 2017). A difference between low and high hypnotizability groups may reflect an atypical neurophysiological profile in low hypnotizable individuals, rather than in high hypnotizable individuals (Terhune et al., 2017). Studies III and IV included high, medium and low hypnotizable participants, whereas Studies I and II were conducted with only a single group of highly hypnotizable participants. Study I, also including low and medium hypnotizables might have revealed more information. Notably, high and low hypnotizables have exhibited different EEG patterns in some studies (Cardena et al., 2013; Williams & Gruzelier, 2001), and the elevated theta power in hypnosis, compared to the wake state, has also been observed in low hypnotizables (Sabourin et al., 1990). However, since in Study I no hypnosis-related increase in theta power (or even a trend toward it) was observed in highly hypnotizable participants, it is unlikely that an increase could have been found in low or medium hypnotizable participants either. In a similar retrospective evaluation of Study II, since no statistically significant effects of hypnosis on MMN were obtained with the highly hypnotizable participants, the lack of control groups of medium or low hypnotizable participants cannot be considered a serious shortcoming. Based on the results of an earlier study (Facco et al., 2014), it seems unlikely that the suggestion-related effect on MMN could have been found with medium or low hypnotizable groups either, despite their afore-discussed 230-to-280-ms effect.

Study III exploited a shortened version of the CPT task, lasting only 3 minutes, whereas the more commonly used versions may last for 10–30 minutes. A short version was chosen to avoid prolonging the hypnosis sessions unnecessarily. The shorter version may have resulted in fewer errors in the performance of both groups, as mentioned earlier. RTV parameters, being mainly appropriate with clinical groups, were not estimated. Since our primary goal was to examine and compare the performance of ADHD and control participants, the use of standard deviation was considered adequate to describe the inter-individual variation. Since the mean RT of the ADHD participants in PrH was shorter than that of the controls, it is unlikely that the three-minute CPT task could have remarkably contributed to the RTV either.

Study IV had a rather small number of participants (eight in the hypnotherapy and nine in the CBT follow-up), which did not allow us to perform the analysis separately for each hypnotizability group. Another limitation at follow-up was the missing control group, which was not possible for ethical reasons since the participants of the treatment-time control group also received an intervention afterward. In addition, the distribution of the severity of symptoms in CGI ranged from mildly to markedly ill, the most extreme cases were missing in both treatment groups. Consequently, the results of Study IV must be considered with caution and cannot be generalized to the whole ADHD adult population.

6.7 Concluding remarks

The present thesis utilized several different methods in the broad research areas of hypnosis, attention and attention deficits. It addressed research questions that have already been previously studied in the field of experimental and clinical hypnosis (i.e., brain oscillations in hypnosis) but also extended to areas where the previous research was scarce or non-existent.

No evidence was found in highly hypnotizable subjects for the proposal, derived from the results of earlier studies, that an increase of theta power would be a reliable marker of the hypnotic state. Also contrary to several previous results, hypnosis and hypnotic suggestions were not found to have an effect on the preattentive MMN brain response.

Hypnotic suggestions, in turn, were clearly found to improve performance in a voluntarily-controlled auditory sustained-attention task in both healthy participants and ADHD adults. The results of the latter group, together with the outcome of the six-month follow-up of hypnotherapy treatment, indicated that hypnosis is also well-suited for treating adults with ADHD. The long-term treatment outcome of hypnotherapy was found to be stronger and more stable than that of the CBT. The latter has thus far been regarded as the best evidence-based psychological treatment for adults with ADHD. Further studies on applying hypnotherapy for adults with ADHD are warranted to confirm the results from these pilot studies and to verify which hypnosis-related factors are responsible for the better long-term stability of the therapeutic effects.

In conclusion, the present thesis has progressively built a new understanding of hypnosis and its capabilities and limitations in the research and treatment of attentional functions and their deficits.

7 References

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