A scientific exploration of the effects of autosuggestion on perceptual modulation

Thesis

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Preamble

The results of the present work were published in the following:

1. Myga, K. A., Kuehn, E., & Azanon, E. (2022). Autosuggestion: a cognitive process that empowers your brain? *Experimental Brain Research*, *240*(2), 381-394. https://doi.org/10.1007/s00221-021-06265-8

Text sections and graphs from the above-mentioned published manuscript were used in Chapters 1 and 2.

2. Myga, K. A., Kuehn, E., & Azañón, E. (2024). How the inner repetition of a desired perception changes actual tactile perception. *Scientific Reports*, *14*(1), 3072. https://doi.org/10.1038/s41598-024-53449-7

Text sections and graphs from the above-mentioned published manuscript were used in Chapter 3.

3. Myga, K. A., Longo, M. R., Kuehn, E., Azañón (2025). Autosuggestion and Mental Imagery Bias the Perception of Social Emotions. *bioRxiv*. https://doi.org/10.1101/2025.01.09.632121

Text sections and graphs from the manuscript mentioned above, published in the preprint server were used in Chapter 6.

This thesis was written using AI tools such as Grammarly, ChatGPT, and Perplexity to improve grammar, flow, and clarity of the written content.

Abstract

The concept of autosuggestion, introduced by Émile Coué, is central to self-help literature yet remains underexplored scientifically. Rooted in the notion that "thoughts create reality," autosuggestion posits that individuals can shape their cognition, emotional well-being, and health outcomes. Despite the popularity of practices like positive affirmations, the mechanisms and efficacy of autosuggestion are poorly understood. This doctoral thesis addresses these gaps by systematically reviewing existing research and conducting novel experimental investigations to examine autosuggestion's mechanisms, efficacy, and limitations.

To establish a scientific foundation, this thesis conceptualizes autosuggestion as the instantiation and reiteration of ideas or concepts by oneself, aimed at influencing mental, physiological, and interoceptive states and the valence of perceived sensations. Comprising 11 experiments with results analyzed from 227 participants, this thesis explores whether autosuggestion can reliably modulate human cognition and perception. Using rigorous experimental paradigms that minimize demand characteristics, this work provides a framework for understanding autosuggestion and its potential effects.

Structured into seven chapters, the thesis begins by introducing the concept and reviewing existing literature. Experimental findings then examine autosuggestion's influence on perception, including tactile intensity, body representation, and emotion perception.

In tactile perception, we investigated whether autosuggestion could alter the perceived intensity of vibrotactile stimuli while addressing potential demand characteristics through a carefully controlled manipulation. Using a paradigm based on the established frequency-intensity coupling phenomenon (the "Békésy effect"), participants were instructed to autosuggest changes in the perceived intensity of stimuli while reporting perceived frequency (i.e., response orthogonal to the variable of interest). We found that participants with positive associations reported higher perceived frequencies when they autosuggested stronger intensity and lower frequencies when they autosuggested weaker intensity. Nonetheless, participants with negative associations demonstrated opposing effects. Also, subsequent modifications to this paradigm in a follow-up study comparing autosuggestion to placebo abolished the observed effects, suggesting experimental design nuances significantly influence outcomes.

In body representation, we investigated the effects of autosuggestion on ownership of rubber hands and spatial representation of participants' real hands. Participants autosuggested ownership of uncrossed rubber hands positioned above their occluded real hands while performing a tactile temporal-order judgment task with their real hands crossed. We found no significant differences between this manipulation and the two control conditions (autosuggestion that the hands belonged to another person and no autosuggestion). These results suggest either the robustness of the crossed-hands deficit or a dissociation between autosuggestion and body representation. This highlights the need for refined methodologies to explore this interaction further.

For emotion perception, an adaptation paradigm assessed whether autosuggestion could modulate facial emotion perception. Participants autosuggested that a neutral face appeared happy or sad, producing assimilative aftereffects, where test faces were perceived as more similar to the suggested emotion. Despite instructions to avoid mental imagery, participants often used it, prompting follow-up experiments to isolate imagery's role. Independent tests of mental imagery produced similar aftereffects, suggesting that cognitive processes influence emotion perception beyond verbal affirmations. A control experiment using only emotion-related words showed no effects, confirming genuine perceptual changes rather than response bias. Further experiments replicated contrastive aftereffects through exposure to emotional faces, validating the paradigm and underscoring the role of both autosuggestion and mental imagery in modulating emotion perception.

The thesis concludes with insights that redefine autosuggestion, suggesting it involves intentional, individualized strategies rather than solely verbal repetition. Across studies, participants used diverse cognitive strategies, such as mental imagery and contextual visualization, to override current perceptual states. While results varied, they highlight the complexity of autosuggestion and its potential as a self-directed tool for cognitive and perceptual modulation.

This thesis provides the first comprehensive investigation of autosuggestion across sensory and emotional domains, highlighting its potential while acknowledging its variability. Future research should involve larger samples, integrate neuroimaging, and explore individual differences in suggestibility and cognitive strategies. These efforts will further clarify autosuggestion's mechanisms and applications in clinical and everyday contexts, advancing its systematic scientific exploration.

Zusammenfassung

Das von Émile Coué eingeführte Konzept der Autosuggestion spielt in der Selbsthilfeliteratur eine zentrale Rolle, ist aber wissenschaftlich noch nicht ausreichend erforscht. Ausgehend von der Vorstellung, dass „Gedanken die Wirklichkeit erschaffen“, geht Autosuggestion davon aus, dass der Einzelne seine Kognition, sein emotionales Wohlbefinden und seine Gesundheitsergebnisse beeinflussen kann. Trotz der Beliebtheit von Praktiken wie positiven Affirmationen sind die Mechanismen und die Wirksamkeit der Autosuggestion nur unzureichend erforscht. Die vorliegende Doktorarbeit befasst sich mit diesen Lücken, indem sie bestehende Forschungsarbeiten systematisch auswertet und neue experimentelle Untersuchungen durchführt, um die Mechanismen, die Wirksamkeit und die Grenzen der Autosuggestion zu untersuchen.

Um eine wissenschaftliche Grundlage zu schaffen, konzeptualisiert diese Arbeit Autosuggestion als die Instanziierung und Wiederholung von Ideen oder Konzepten durch sich selbst, die darauf abzielt, mentale, physiologische und interozeptive Zustände und die Valenz von wahrgenommenen Empfindungen zu beeinflussen. In dieser Doktorarbeit wird anhand von 11 Experimenten mit 227 Teilnehmern untersucht, ob Autosuggestion die menschliche Kognition und Wahrnehmung zuverlässig modulieren kann. Unter Verwendung strenger experimenteller Paradigmen, die die Anforderungen minimieren, bietet diese Arbeit einen Rahmen für das Verständnis der Autosuggestion und ihrer potenziellen Auswirkungen.

Die Arbeit ist in sieben Kapitel gegliedert und beginnt mit einer Einführung in das Konzept und einer Übersicht über die vorhandene Literatur. Anschließend wird in Experimenten der Einfluss von Autosuggestion auf die Wahrnehmung untersucht, einschließlich der taktilen Intensität, der Körperrepräsentation und der Emotionswahrnehmung.

Im Bereich der taktilen Wahrnehmung untersuchten wir, ob Autosuggestion die wahrgenommene Intensität vibrotaktiler Stimuli verändern kann, wobei wir durch eine sorgfältig kontrollierte Manipulation potenzielle Anforderungsmerkmale berücksichtigten. Mithilfe eines Paradigmas, das auf dem bekannten Phänomen der Frequenz-Intensitäts-Kopplung (dem „Békésy-Effekt“) basiert, wurden die Teilnehmer angewiesen, Änderungen in der wahrgenommenen Intensität von Stimuli automatisch zu suggerieren, während sie die wahrgenommene Frequenz (d. h. die orthogonale Antwort auf die interessierende Variable) angaben. Wir fanden heraus, dass Teilnehmer mit positiven Assoziationen höhere wahrgenommene Frequenzen angaben, wenn sie eine höhere Intensität selbst vorschlugen, und niedrigere Frequenzen, wenn sie eine geringere Intensität selbst vorschlugen. Teilnehmer mit negativen Assoziationen zeigten jedoch gegenteilige Effekte. In einer Folgestudie, in der Autosuggestion mit Placebo verglichen wurde, wurden die beobachteten Effekte durch nachträgliche Modifikationen dieses Paradigmas aufgehoben, was darauf hindeutet, dass Nuancen in der Versuchsplanung die Ergebnisse erheblich beeinflussen.

Bei der Körperrepräsentation untersuchten wir die Auswirkungen der Autosuggestion auf den Besitz von Gummihänden und die räumliche Repräsentation der echten Hände der Teilnehmer. Die Teilnehmer suggerierten den Besitz von ungekreuzten Gummihänden, die über ihren verdeckten realen Händen lagen, während sie eine taktile Aufgabe zur Beurteilung der zeitlichen Reihenfolge mit gekreuzten realen Händen durchführten. Wir fanden keine signifikanten Unterschiede zwischen dieser Manipulation und den beiden Kontrollbedingungen (Autosuggestion, dass die Hände zu einer anderen

Person gehörten und keine Autosuggestion). Diese Ergebnisse deuten entweder auf die Robustheit des Defizits bei gekreuzten Händen oder auf eine Dissoziation zwischen Autosuggestion und Körperrepräsentation hin. Dies unterstreicht die Notwendigkeit verfeinerter Methoden zur weiteren Erforschung dieser Interaktion.

Bei der Emotionswahrnehmung wurde mit einem Anpassungsparadigma untersucht, ob Autosuggestion die Wahrnehmung von Gesichtsemotionen modulieren kann. Die Teilnehmer schlugen selbst vor, dass ein neutrales Gesicht glücklich oder traurig erscheinen sollte, was zu assimilativen Nacheffekten führte, bei denen die Testgesichter als der vorgeschlagenen Emotion ähnlicher wahrgenommen wurden. Obwohl die Teilnehmer angewiesen wurden, mentale Bilder zu vermeiden, nutzten sie diese häufig, was zu Folgeexperimenten führte, um die Rolle der Bilder zu isolieren. Unabhängige Tests mit mentalen Bildern ergaben ähnliche Nacheffekte, was darauf hindeutet, dass kognitive Prozesse die Emotionswahrnehmung über verbale Bestätigungen hinaus beeinflussen. Ein Kontrollexperiment, bei dem nur emotionsbezogene Wörter verwendet wurden, zeigte keine Auswirkungen, was bestätigt, dass es sich um echte Wahrnehmungsveränderungen und nicht um eine Reaktionsverzerrung handelt. Weitere Experimente wiederholten die kontrastiven Nacheffekte durch die Exposition gegenüber emotionalen Gesichtern, was das Paradigma bestätigte und die Rolle sowohl der Autosuggestion als auch der mentalen Bilder bei der Modulation der Emotionswahrnehmung hervorhob.

Die Arbeit schließt mit Erkenntnissen, die Autosuggestion umdefinieren und darauf hindeuten, dass es sich dabei um intentionale, individualisierte Strategien handelt und nicht nur um verbale Wiederholungen. In allen Studien setzten die Teilnehmer verschiedene kognitive Strategien ein, wie z. B. mentale Bilder und kontextuelle Visualisierung, um aktuelle Wahrnehmungszustände außer Kraft zu setzen. Auch wenn die Ergebnisse unterschiedlich ausfielen, verdeutlichen sie die Komplexität der Autosuggestion und ihr Potenzial als selbstgesteuertes Instrument zur kognitiven und wahrnehmungsbezogenen Modulation.

Diese Arbeit stellt die erste umfassende Untersuchung der Autosuggestion in sensorischen und emotionalen Bereichen dar und hebt ihr Potenzial bei gleichzeitiger Anerkennung ihrer Variabilität hervor. Zukünftige Forschungsarbeiten sollten größere Stichproben einbeziehen, Neuroimaging integrieren und individuelle Unterschiede in der Suggestibilität und den kognitiven Strategien untersuchen. Diese Bemühungen werden die Mechanismen und Anwendungen der Autosuggestion in klinischen und alltäglichen Kontexten weiter klären und ihre systematische wissenschaftliche Erforschung vorantreiben.

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Chapter 1

Organization of the thesis

"Every day, in every way, I'm getting better and better."

Emile Coué

The idea that "thoughts create reality" has gained popularity in modern life, suggesting that individuals can significantly influence their circumstances, emotional well-being, and health outcomes. The concept of autosuggestion originates from the pioneering work of Coué in the early twentieth century who observed that people's mental states can affect the outcomes of medical treatments (Baudouin, 1923; Yeates, 2016a). Autosuggestion assumes that individuals can shape their perceptual and brain states by repeating specific suggestions (Baudouin, 1923; Myga et al., 2022). A popular example of autosuggestion are positive affirmations, which people tell themselves to improve their experiences (Myga et al., 2022). Nevertheless, whether autosuggestion really works and descriptions of the mechanisms underlying autosuggestion remain lacking. This thesis addresses the existing gap in the scientific literature on autosuggestion. By conducting a systematic review of current research and undertaking empirical investigations, this doctoral work seeks to provide a thorough understanding of the concept of autosuggestion and its relevance in today's practice. This research will explore possible underlying mechanisms, evaluate the effectiveness, and identify the potential limitations of autosuggestion through rigorously designed experimental paradigms. Ultimately, this thesis aspires to advance theoretical insights and practical applications of autosuggestion in various fields.

This thesis is structured into seven chapters, each focusing on a specific aspect of autosuggestion within a scientific framework (see **Figure 1**). The chapters are structured to build on each other, forming a narrative that deepens our understanding of the different effects of autosuggestion. The current chapter represents a brief overview of autosuggestion and the motivations behind this research. The following chapters will review the existing literature on autosuggestion and present the empirical findings of experiments conducted for this thesis which will carefully investigate whether and how autosuggestion influences perception.

Please note that throughout this thesis, pronoun use has been cautiously taken into account to reflect not only the collaborative effect of the research but also the individual contribution. The words "we" and "our" will be used when discussing the studies conducted for this thesis to credit my supervisor and team of collaborators for this collective effort. Yet, when referring to the whole structure and presentation of this thesis, I use "I" to reflect the personal responsibility for its design.

Chapter 2 provides a thorough literature review on autosuggestion and its related phenomena. It provides evidence that top-down mechanisms, such as autosuggestion and its related phenomena, such as placebo, autogenic training, or imagery, can lead to behavioral, cognitive, and neural changes within the body.

Chapter 3 presents the findings from Study 1, investigating the impact of autosuggestion on participants' tactile perceptions. Across three experiments, participants were asked to internally repeat the thought that the sensations felt very strong (Experiment 1) or very weak (Experiments 2 and 3), to modulate the perceived intensity of tactile stimuli on the fingertip. Meanwhile, they were asked to report the perceived frequency of the stimulation. We found that manipulating the perceived intensity of touches influenced their perceived frequency (a phenomenon known as the Békésy effect; von Békésy, 1959). These findings cast light on the ability of autosuggestion to alter tactile intensity perceptions and highlight individual differences that may influence its effectiveness.

Chapter 4 presents the results from Study 2, which builds upon the methodology and principles of Study 1. In two experiments, autosuggestion is compared directly to placebo effects in a refined within-participant design. Participants underwent a placebo manipulation using a transcranial direct current stimulation (tDCS) mimicking device, where they were told that the current delivered by this device would make the touches at the fingertips feel stronger or weaker. They were then re-tested after a couple of weeks, this time using autosuggestion to intentionally alter the perception of touches. Contrary to our hypotheses, the results of both experiments showed no effects of any of the manipulations, highlighting possible methodological factors that might have influenced participants' engagement and overall experimental outcomes.

Chapter 5 reports the results of Study 3, which investigates the influence of autosuggestion on body representation (body schema). Using an implicit experimental method, the present study investigates the effect of autosuggestion on the crossed-hands deficit – a phenomenon where performance in judging the order of tactile stimuli is impaired when the hands are crossed relative to the uncrossed. Participants autosuggested that rubber hands placed on a platform belonged to them (*autosuggestion self* condition) or to their best friend (*autosuggestion other* condition) or they thought of nothing in particular (*no autosuggestion* condition). Although the results were not significant, the chapter discusses trends and possible implications of autosuggestion for the modified perception of body posture.

Chapter 6 presents Study 4, which investigates the effects of autosuggestion on emotion perception, comparing it with mental imagery and semantic processing, using an adaptation paradigm. Adaptation aftereffects refer to systematic changes in perception resulting from extended exposure to specific types of stimuli. Participants were asked to mentally affirm in Experiments 1a and 1b or imagine in Experiment 2 a neutral face as happy or sad and then rating test faces along a happiness-sadness continuum. We found biases induced by both autosuggestion and imagery, where participants perceived the test faces as more similar to the autosuggested or imagined emotion (assimilative aftereffects). To rule out response bias, Experiment 3 exposed participants to emotional words, yielding no significant effects. Experiment 4 validated the experimental design by demonstrating standard contrastive aftereffects after adaptation to happy or sad faces. This chapter provides an in-depth review of potential mechanisms underlying such perceptual biases and discusses possible interactions between autosuggestion and imagery processes.

The final chapter containing the General discussion summarizes key findings and addresses limitations and methodological challenges encountered. Possible mechanisms underlying autosuggestion are described as well as recommendations for future research on autosuggestion.

Though outside the focus of this thesis, Appendix 1 includes a jointly authored paper titled "Haptic Experience of Bodies Alters Body Perception" co-authored with Elena Azañón, Klaudia B. Ambroziak, Elisa R. Ferrè, and Matthew R. Longo (Myga et al. 2024a), which was developed concurrently with my PhD program. Literature is full of evidence showing that frequent visual exposure (i.e., "visual diet") to extreme body types leads to perceiving the average body type as opposed to the frequently exposed. These effects are usually investigated in the context of body attractiveness (Boothroyd et al., 2012; Mele et al., 2013; Winkler & Rhodes, 2005) and normality (Glauert et al., 2009; Hummel et al., 2012; Winkler & Rhodes, 2005) and are measured using adaptation paradigms (Frisby, 1979). While prior studies have mainly focused on how visual media shapes body perception, the research neglected other sensory perceptual modalities, such as haptics. This study investigates how haptic experience of extreme body shapes affects average body perception, and how this compares to visual experience. For the first time, we show that adiposity aftereffects in the haptic domain using 3D printed dolls with different body sizes, were similar to those previously observed in vision, using matching stimuli in both, haptic and visual paradigms. The methods and analyses employed in this study closely mirror those used in Study 4, ensuring methodological coherence within the broader context of this thesis.

Through this structured approach, this thesis aims to provide a comprehensive overview of autosuggestion, addressing gaps in the existing literature and offering valuable insights for researchers, practitioners, and individuals interested in exploring the potential of autosuggestion for personal growth and well-being.

Chapter 1

Organization of the thesis

- ✓ Placing autosuggestion within the scientific context
- ✓ Brief introduction to each chapter's content

Chapter 2

General introduction

- ✓ Reviewing autosuggestion research, identifying literature gaps, and situating this thesis within them
- ✓ Introducing the definition of autosuggestion
- ✓ Differentiating autosuggestion from related concepts:
  - imagery, bodily attention, and mental simulation
  - implementation intentions and reappraisal
  - heterosuggestion and hypnosis, and placebo

Chapter 3

Autosuggestion and tactile perception

- ✓ Testing the ability of autosuggestion to alter tactile intensity perceptions
- ✓ Using implicit measurement by employing tactile intensity and frequency associations (i.e., Békésy effect)
- ✓ Contrasting strong (Exp. 1) or weak (Exp. 2 and 3) condition against the baseline
- ✓ Categorizing participants based on their associations between intensity and frequency
- ✓ Discussing individual differences that could have influenced the effects of autosuggestion

Chapter 4

Comparing autosuggestion and placebo effects in touch

- ✓ Comparing placebo (Exp. 1) with autosuggestion (Exp 2) within the same subjects
- ✓ Introducing modifications to the paradigm used in Chapter 3 to strengthen the effect sizes:
  - conditioning trials
  - catch trials
  - contrasting the strong versus the weak condition
- ✓ Exploring the adverse effects of modifying the paradigm and the null results in both experiments

Chapter 5

Autosuggestion and body schema

- ✓ Using an implicit method to investigate the effects of autosuggestion on body schema:
  - incorporating the rubber hand paradigm to autosuggestion that rubber hands belong to the participant or another person (control 1), or no autosuggestion (control 2)
  - measure outcome: the magnitude of the crossed hands deficit measured by indicating the temporal order of touches delivered to real crossed hands
- ✓ Discussing trends in the results, despite the lack of statistical significance

Chapter 6

Autosuggestion and emotion perception

- ✓ Testing the impact of autosuggestion on emotion perception (Exp. 1a) with stricter imagery limits (Exp. 1b), using an adaptation paradigm
- ✓ Comparing the effects of imagery (Exp. 2) on emotion perception with autosuggestion (Exp. 1a and 1b)
- ✓ Conducting Experiment 3 with emotional words to control response bias
- ✓ Validating the experimental design using stimuli depicting actual happy and sad expressions (Exp. 4)
- ✓ Discussing the assimilative effects in Experiments 1a-b and 2, and exploring autosuggestion-imagery interactions

Chapter 7

General discussion

- ✓ Summarizing key findings from the studies
- ✓ Describing possible mechanisms underlying autosuggestion:
  - semantic and conceptual processing
  - involvement of mental imagery
  - attentional processes
- ✓ Discussing encountered limitations and methodological challenges
- ✓ Providing recommendations for future research on autosuggestion

Figure 1. Progression of thesis and main concepts discussed in thesis chapters.

Chapter 2

General introduction

This chapter is based on content originally published in "Myga, K. A., Kuehn, E., & Azanon, E. (2022). Autosuggestion: a cognitive process that empowers your brain?. *Experimental Brain Research*, *240*(2), 381-394. https://doi.org/10.1007/s00221-021-06265-8". While most of the chapter has been extensively rewritten, a few sections, including text, tables, and figures, may be identical to the published work to ensure the accuracy and integrity of the original findings.

The concept of autosuggestion is based on the captivating idea that an individual can control widespread cognitive and physiological brain states. Autosuggestive techniques date back to the late nineteenth century when Emilé Coué introduced autosuggestion. As an owner of a pharmacy, Coué was trained in examining, diagnosing, and prescribing medication to patients. However, he started treating his patients beyond the prescribed medicines, including cognitive interventions (Paulhus, 1993; Yeates, 2016a). Through constant interactions with different clinical cases, Coué realized the importance of one's own *attitude* towards the illness and the future outcomes of the healing process. He adopted the so-called "Braid's-style hypnotism", which concentrates on the "activation of those forces of the mind that can induce cognitive changes in oneself" (Yeates, 2016b). Specifically, Braid promoted the so-called monoideism, the concentration of attention toward a single object (Kihlstrom, 2008), which was further developed in Coué's interventions. Coué began to investigate the effect of directing attention toward the desired outcome and repeating confirmative sentences specifying this outcome in the later healing process. This inspired him to develop the concept of autosuggestion, stating that *an idea that is exclusively occupying the mind turns into reality, although only to the extent that the idea is within the realm of possibility* (Baudouin, 1920, 1923; Coué, 1922).

When defining conditions and rules for successful autosuggestion, Coué emphasized the so-called "Law of Reversed Effort", which states that in cases of conflict between the active, conscious striving for action (e.g., employing thoughts targeting to trigger healing processes within the body) and the formation of ideas, images, or concepts on future achievements (e.g., remission of a disease), the *belief* of what is possible always wins (Baudouin, 1920, 1923). This belief of what is possible coupled with the belief in one's ability to influence one's own cognitive or bodily states seems to be a modulating factor for successful autosuggestion. This belief in being able to influence events in one's own life is an element constituting the concept of self-efficacy pinpointed by Bandura (Bandura, 1977). Only if people believe in their capabilities to achieve certain goals (e.g., in the case of autosuggestion: evoking desired subjective experience), will they have the motivation to do necessary action (here: activating cognitive resources underlying autosuggestion). However, Coué never provided empirical evidence for his claims but rather offered case examples in his publications (Baudouin, 1920; Coué, 1922). He nevertheless became popular for this method in his lifetime and disseminated his techniques to other health practitioners at the national and international level (Paulhus, 1993; Yeates, 2016b, 2016a).

Since then, autosuggestive techniques have been an integral part of our modern life. For example, a popular form of applied autosuggestive techniques are positive affirmations (i.e., statements of desired outcomes that people repeat to themselves). Nevertheless, there is still a lack of comprehensive descriptions regarding the cognitive and neural mechanisms that underlie autosuggestion, as well as its similarities and differences to related concepts. Research questions such as "How can autosuggestion be defined in light of modern cognitive neuroscience?" and "How can autosuggestion be experimentally induced in a laboratory setting?" remain unanswered. This knowledge gap limits the potential impact of autosuggestion in various scientific and clinical fields, such as therapies for chronic pain or rehabilitation, where its application is still underexplored.

In this chapter, we review the evidence on autosuggestion and related phenomena, with a focus on mental imagery, mental simulation, and heterosuggestion including placebo and hypnosis. Our goal is to clarify these concepts at both theoretical and practical levels while identifying and defining the cognitive features that are unique to autosuggestion. We review past experimental attempts to induce autosuggestion, highlighting their strengths and weaknesses. Evidence gathered here will help to make autosuggestion a future target for empirical research in cognitive neuroscience, ultimately contributing to the development of evidence-based cognitive therapies in the mental health sector.

Whereas autosuggestion can be discussed in various contexts (Ludwig et al., 2014; Sari et al., 2017; Schlamann et al., 2010), this discussion focuses on its influence on sensorimotor processing and the perception of touch and pain. Sensorimotor systems provide an excellent model for investigating precise sensory encoding principles, which can be tested through rigorous and replicable experimental paradigms. Additionally, the potential to apply these insights to alter the perception of touch and pain makes this area particularly valuable for both basic and applied research. Autosuggestion refers to the process in which the repetition of a specific thought leads to changes in perceptual and/or brain states.

Self-induced suggestion differs from heterosuggestion, because the latter implies that suggestions are reinforced by *another person*, whereas in autosuggestion, the suggestions are reinforced by *the to-be-suggested person* (see **Box 1**). We define autosuggestion as the *instantiation and reiteration of ideas or concepts* by *oneself* aiming to *actively bias one's own perceptual, brain or interoceptive states, as well as the valence of perceived sensations*. *This reiteration takes a verbal/linguistic form (internally or out loud) and may be reinforced by employing imagery. Autosuggestion may take both forms: implicit (i.e., adopted and internalized suggestion from external sources) and explicit (applied consciously and volitionally).* The focus of this thesis is on the explicit (conscious) forms of autosuggestion set out for the beneficial effects of the user. The word "actively" indicates that autosuggestion is voluntary and intentional, and links to concepts such as agency or free will (see below). Intention is directed towards a *predefined outcome, often contradictory to the existing experience,* to bias subsequent perceptual or brain states. This influence is assumed to be reflected at a phenomenological, behavioral, and neurophysiological level (see below).

The question of whether one's own mind has the capacity to influence one's own perceptual experience has been debated by philosophers, psychologists, and neuroscientists for centuries (e.g., Fuchs, 2006; Hegel & Inwood, 2007; Leaf, 2013). The intention here is not to reignite this debate; instead, we concentrate on the available experimental evidence from cognitive neuroscience that offers empirical data regarding the factors that facilitate or hinder the ability to alter one's own brain and perceptual states in an experimental context. For example, it has been shown that placebo suggestions can modify functional activation and related pain thresholds at the level of the spinal cord through downstream projections (Eippert et al., 2009; Wright, 1995), and neural activity often reflects inferred rather than actual brain states, for example via predictive coding (Barron et al., 2020; Friston, 2012; Kok & De Lange, 2015). Similarly, modern cognitive neuroscience provides empirical evidence that cognitive states that are believed, observed, or predicted can modulate basic neurophysiological processes at the level of the spinal cord, subcortical structures (Sedley et al., 2016), or primary sensory cortices (Kuehn et al., 2018). These data form the basis for the concept and discussion of autosuggestion carried out in this thesis to provide a comprehensive overview of the shared and distinctive features of autosuggestion in relation to other phenomena.

Box 1. Definitions
Autosuggestion Instantiation and reiteration of ideas or concepts by oneself aiming to actively influence one's own mental, physiological and interoceptive states, as well as the valence of perceived sensations. This reiteration takes a verbal/linguistic form (internally or out loud) and may be reinforced by employing imagery. Autosuggestion may take both forms: implicit (i.e., adapted and internalized suggestion from external sources) and explicit (applied consciously and volitionally), and be set for both, positive and negative outcomes. Autosuggestion is a proactive form of self-regulatory mechanism activated during early stages of perceptual processing.
Suggestion A thought or an idea that influences cognitive and physiological states.
Heterosuggestion A process used by one individual to influence the cognitive and physiological states of another individual through direct or indirect suggestion.
Mental imagery Experience that mimics perception but occurs in the absence of sensory input.
Autogenic training A relaxation technique composed of multiple sub-parts aimed at facilitating desired bodily perceptions.
Hypnotic suggestion The phenomenon whereby one individual gives a series of instructions to another individual aiming at modifying a range of subjective experiences and behaviors within a person being hypnotized.
Implementation intentions The process of planning to respond to a certain situation in a specific way to assure a specific goal attainment.
Reappraisal Process of changing an emotional response to a situation by thinking differently about the situation.

Box source: Myga et al., *Exp. Brain Res.*, 2022, p. 383.

2.1 Empirical evidence on autosuggestion and related phenomena

The idea that suggestion can influence perceptual states is in line with our everyday experiences. For example, we can easily bring about the sensation of hunger if we mistakenly believe it is lunchtime (Parkyn, 1909), and thinking of itching is sufficient to produce the itching sensation at a specific part of the body. Moreover, our expectations or predictions about future states can affect neural activity: incoming signals that are perceived as surprises are given more weight than those that were predicted (Weiss & Schütz-Bosbach, 2012). But what is the empirical evidence concerning autosuggestion?

We carried out an extensive literature search to identify scientific evidence on autosuggestion. Primarily using Google Scholar, we used terms such as "autosuggestion", "top-down control", "self-suggestion", "self-influence via thoughts", and "self-regulation". The focus was on autosuggestion in the somatosensory context, but we also considered studies from other domains. In most cases, the experimental procedures were not well defined in terms of autosuggestion and did not explicitly distinguish it from other intervention techniques (e.g., Schlamann et al., 2010). To address this, we proposed precise criteria to differentiate between interventions based on the experimental paradigms used (see this Chapter's discussion).

Ludwig et al. (2014) investigated whether autosuggestion and posthypnotic suggestion alter the value people place on unhealthy food during decision-making. In the hypnosis group, participants were suggested that a particular background color on the monitor would be associated with feelings of disgust toward either sweet or salty snacks. Conversely, participants in the autosuggestion group were asked to make the same association by themselves. Both groups participated in an auction for the snacks, while undergoing functional magnetic resonance imaging fMRI measurements. Results revealed that both groups significantly reduced their bidding amounts for snacks associated with disgust. Moreover, a decrease in the blood oxygen level-dependent (BOLD) signal was observed in the ventromedial prefrontal cortex (vmPFC), an area known to represent value, indicating a diminished desire to consume these snacks. Yet, the cue's depreciating effect on the rostral anterior cingulate cortex (rACC) was more pronounced in the hypnosis than in the autosuggestion group. A limitation of this study, however, is that it lacks a control group in which no suggestive intervention was performed, which makes it difficult to dissociate the effects of pure color-value associations from those due to suggestive manipulation. Previous research has indicated that associations linking oneself (in this case, the subject's feelings of disgust) to an object can occur rapidly and without the need for reinforcement of any suggestion (Sui et al., 2009).

Autosuggestion is also used as a mental tool in relaxation practices, such as meditation and autogenic training (AT; Schulz, 1932). Recently Shilpa and colleagues (2020) showed that meditation reinforced by autosuggestion helped to restore cardiovascular balance in healthy young adults, however, the effects of autosuggestion were not tested separately from meditation. During autogenic training, the inner repetition of specific thoughts or phrases is used to elicit somatic sensations (Kanji, 2000). It should be noted that while the sentences used in AT adhere to linguistic rules established for autosuggestion (see below in the Discussion of this chapter), they aim at indirectly inducing relaxation. Instead of directly stating "I feel very relaxed", individuals focus on influencing the perception of various body parts and systems separately, with the goal that these perceptual changes will cumulatively lead to relaxation. This approach targets key areas such as the musculoskeletal system, circulatory system, heart, respiratory system, abdomen, and forehead. Therefore, individuals might repeat thoughts such as "My right arm feels heavy", "My heart feels warm and pleasant", and "My forehead feels cool".

An fMRI study conducted by Schlamann and colleagues (2010) investigated brain activity during three autosuggestive phases of autogenic training (AT) – specifically imagery of feelings of calmness, arm heaviness, and warmth in the arm, however the exact procedure was not described. The study involved participants who were experienced in AT (the AT group) and those who had never practiced it before (the control group). The AT group showed increased activation in the left pre- and postcentral cortices compared to their resting state, while the control group showed more activation in the left parietal cortex and reduced activation in the prefrontal and insular cortices compared to the AT group. Moreover, insular activation was found to correlate with the number of years spent practicing basic relaxation techniques. This study illustrates how focusing on sensations in specific body areas through autosuggestion-like methods can alter brain networks related to top-down control and bodily awareness, especially in individuals familiar with these techniques. However, it is important to note that autosuggestion was confused with imagery, and the actual impact of the experimental manipulation, in comparison to other relaxation methods, was not assessed, as no other techniques were tested against AT.

Autosuggestion can also be integrated into cognitive behavioral therapy (CBT), which aims to reduce symptoms by challenging and adjusting unhelpful thoughts to align with reality (Longmore & Worrell, 2007). One study explored the effect of the CBT intervention on quality of life in acutely ill geriatric patients (Sari et al., 2017). Participants were divided into an autosuggestion group and a control group. Those in the autosuggestion group were instructed to create their own autosuggestive phrases based on their health preferences, following specific guidelines (for details see Sari et al. 2017). These phrases were then recorded in the participants' own voices, and they were asked to listen to these recordings multiple times a day for 30 days. Both groups continued to receive their usual medical treatment. After the intervention, the autosuggestion group reported a higher quality of life, and their serum cortisol levels returned to healthy norms for elderly adults, which was not the case for the control group. These results suggest that autosuggestion improves subjective quality of life and lower stress levels. However, the absence of additional tasks for the control group and the fact that participants listened to recordings instead of generating autosuggestions internally (see **Box 1**) make it challenging to distinguish between related concepts, such as attention and heterosuggestion, as discussed below.

Taken together, the existing literature on explicitly measured autosuggestion is limited (see **Table 1**). The few studies that include aspects of autosuggestion indicate that its use may have positive effects on certain health outcomes, such as restoring hormonal balance, cardiovascular function, and contributing to general well-being (Sari et al., 2017; Shilpa et al., 2020). Furthermore, research shows that the brain regions involved in autosuggestion include the prefrontal and insular cortices (Ludwig et al., 2014; Schlamann et al., 2010). However, these findings are preliminary and require further investigation to establish their reliability and underlying mechanisms. In addition, several other cognitive processes share experimental characteristics with autosuggestion but are linked to different cognitive concepts, such as mental imagery (Anema et al., 2012), mental simulation (Jeannerod & Pacherie, 2004), and bodily attention (Longo al., 2009). We will discuss these processes in the next section in relation to the concept of autosuggestion introduced above.

2.1.1 Autosuggestion versus imagery, bodily attention, and mental simulation

The process of mental imagery has attracted significant interest in cognitive neuroscience over the last decades, with its neural and behavioral correlates extensively studied using techniques such as psychophysics, electroencephalography (EEG), and functional magnetic resonance imaging (fMRI); (Farah, 1985; la Fougère et al., 2010; Linden et al., 2000; Neuper et al., 2005; O'Craven & Kanwisher, 2000; Pfurtscheller & Neuper, 2001; Reddy et al., 2010; Schmidt & Blankenburg, 2019; Yoo et al., 2003). In the sensory domain, mental imagery is defined as a quasi-perceptual experience occurring in the absence of external stimulation (Thomas, 1999). For instance, in the tactile domain, inducing mental imagery in a lab setting often involves instructing participants to "imagine how a surface feels on their skin" while they watch others being touched by different textures (Kuehn et al., 2014), or imagine their finger as numb and less sensitive to pain during painful stimulation (Chaves & Barber, 1974). In vision, researchers often compare the content of visual imagery to actual perception. Participants might be asked to recall objects they have seen before (e.g., a tree) or to assess a faint representation of a real stimulus to determine its properties (e.g., its width, its height; Ganis et al., 2004). Numerous studies have shown that the neural correlates of imagined sensory perceptions, as observed through fMRI, overlap with those activated by real physical stimuli, although they tend to be weaker in amplitude (Ganis et al., 2004; Kosslyn et al., 1997; Kuehn et al., 2014; Schmidt & Blankenburg, 2019; Senden et al., 2019). For example, high-resolution 7-Tesla fMRI data indicated that mental imagery of four letter shapes activated the early visual cortex in a way that maintained the geometric profiles of the letters, despite the absence of retinal stimulation (Senden et al., 2019). The vividness of these imagery experiences has been associated with the strength of neural activations (Amedi et al., 2005).

Similar to autosuggestion, mental imagery can be used to create specific perceptual states. A study by Fardo and colleagues (2015) found that when participants imagined a glove covering their forearm, their perception of painful stimuli in that area decreased (*pain inhibition* condition). Conversely, when they imagined a lesion, their perception of pain increased (*pain facilitation* condition). These shifts in perception were linked to changes in pain-related brain activity, as measured by EEG. In the *pain inhibition* condition, the amplitude of N2 pain-related evoked potentials was higher than the baseline, while the opposite was true in the *pain facilitation* condition. This indicates that mental imagery can produce perceptual and neurophysiological effects similar to those that might be achieved through autosuggestion (e.g., pain reduction). However, the cognitive processes behind each method may differ. In Fardo et al.'s study, the effects resulted from participants imagining external objects, such as a glove or a lesion, rather than directly trying to change the current perceptual state. In contrast, autosuggestion involves participants actively trying to modify specific perceptual experiences to reach predetermined states (i.e., reduce the actual pain perception). These two approaches may engage partially different neuronal networks.

In experimental settings, mental imagery is typically induced by presenting participants with the experience to be imagined either before or during the experiment, or by using familiar content that is expected to be part of their daily lives. Participants are then asked to recall or simulate that experience. For instance, participants may be asked to imagine a green apple and change its color, size, or even to rotate it in their mind's eye. In contrast, autosuggestion involves asking participants to modify an *ongoing* perceptual experience by directly altering the perceptual process itself, for example, by reducing their pain perception. In this respect, there is a conceptual difference between asking participants to "remember the pleasant touch that you felt at the beginning of the experiment", and asking participants to autosuggest that "the touch that you will feel next feels pleasant" despite the touch feeling neutral or unpleasant. This distinction emphasizes the significance of the instructions and experimental framework provided to participants in a laboratory setting (see **Figure 2**). Thus, in experiments designed to test the effects of autosuggestion, participants should be asked to modulate the current cognitive or physiological experience iteratively and dynamically to reach the desired outcome.

Both inhibitory and facilitatory mechanisms likely play a role in autosuggestion and mental imagery. Even if mental imagery may suppress an ongoing experience (such as reducing pain by imagining a protective glove), this inhibition tends to be an indirect "side effect". On the other hand, autosuggestion seems to more directly inhibit an unwanted perceptual state to allow a desired one to emerge. However, it remains uncertain whether autosuggestion involves suppressing an existing perceptual state and generating a new one (which may engage different brain networks), or if the original perceptual state is simply biased and "overwritten".

Facilitatory processes are also crucial in both mental imagery and autosuggestion. In each case, the imagined or autosuggested state aims to induce measurable changes at the perceptual or neural level.

Autosuggestion, in particular, is a deliberate process that requires cognitive engagement to achieve the desired outcome in the physical world. The effectiveness of autosuggestion may depend on two main mechanisms: reactivating previously inhibited brain networks (disinhibition) or activating previously inactive networks (facilitation). Both processes could play a role in realizing the intended effects of autosuggestion.

Table 1. Overview of studies assessing autosuggestion and related phenomena.

Phenomena measured	Definition	Sample size	Dependent variables	Control group	Methods	Results	Reference
Autosuggestion	Not given	N total = 60, aged ≥ 60, 30 per gr.	- quality of life ratings - levels of serum cortisol concentration - levels of immunity markers	Yes	- pre-recorded tapes - QoL chart - measurements in cortisol level and psycho-neuro-endocrine immunology markers by magnetic resonance spectroscopy	- higher QoL scores in A group - serum cortisol reaching healthy norms in A gr. - increase in immunity markers in A group	Sari et al., 2017
Autosuggestion, meditation	Autosuggestion- a form of self-hypnosis, affirmations, a positive self-talk.	N total = 60, 30 per gr.	- heart rate - postural changes in blood pressure -R-R interval (indicative of autonomic tone)	Yes	- loosening exercise - breathing exercise - OM meditation - pre-recorded tapes	- autosuggestion and meditation greater heart rate decrease than meditation alone (but ns.) - both groups: significant reduction in blood pressure, no sig. diff. between groups - improved autonomic tone, no sig. diff. between groups	Shilpa et al., 2020
Posthypnotic suggestion, autosuggestion	Autosuggestion - process of implementing a mental change in oneself (e.g. by repeating suggestions to oneself and by engaging in goal-directed imagery).'	N total = 32, 16 per gr.	- number of bids for sweet/salty snacks - BOLD signal levels in vmPFC	No	- fMRI - questionnaire - behavioral: decision making	- snack devaluation by both H and A - effects stronger in hypnosis - decreased BOLD signal in the vmPFC	Ludwig et al., 2014
The first three autosuggestive phases of AT, motor imagery	Not given	N total = 38, 19 per group	- BOLD signal levels in experimental tasks and resting state	Yes	-fMRI -questionnaires -motor imagery	- left parietal cortex activation during the first two steps of AT in contrast to resting state in controls - higher activation of prefrontal and insular cortices in AT group - higher activation in sensory-motor areas (*) during imagery task in AT group as compared to controls	Schlamann et al., 2010
Verbal suggestion/placebo	Placebos – a set of words, rituals, symbols and meanings' that can change the brains of the patients' (Benedetti et al., 2011)	N = 24, 14 in placebo-like gr., 10 in control gr.	- amplitude measurements of late SEPs (N140 and P 200) before and after treatment	Yes	- electrical stimulation - baseline session, experimental manipulation and final recording	- no increase of tactile sensation after the treatment - no modification in late SEPs	Fiorio, Recchia, Corra, & Tinazzi, 2014

Table 1. Overview of studies assessing autosuggestion and related phenomena. – table continuation.

Phenomena measured	Definitions	Sample size	Dependent variables	Control group	Methods	Results	Reference
Positive and negative Suggestion/Placebo effects	Not given	N = 36, 13 per gr.	- pain threshold, pain tolerance and pain endurance measures	Yes	- hand immersion in ice cold water	- higher pain thresholds, greater pain tolerance and greater pain endurance in PP gr. compared to other groups	Staats, Hekmat, & Staats, 1998
Placebo analgesia effects	Not given	N = 24 (exp 1) N = 23 (exp 2)	- BOLD signal on placebo analgesia - PFC activation during pain anticipation - subjective pain ratings	Yes	- fMRI - painful stimulation - placebo analgesia	- reduced activity in the thalamus, insula, and ACC after placebo analgesia - increased activity during anticipation of pain in PFC and midbrain - greater reported pain for control than placebo	Wager et al., 2004
Autogenic training (AT), cognitive self-hypnosis (CSH)	Not given	N = 156, 58 outpatient neurological patients, 48 community members, 40 students	- treatment outcomes for chronic headaches - relations of level of hypnotizability to treatment outcome - subject recruitment on treatment outcome - use of analgesic medication	Yes	- pretreatment, post-treatment (week 8) and follow-up (week 35)	- reduction in HI scores in experimental groups compared to controls during treatment - reduction in HI scores in AT group at post treatment differed sig. from WLC gr. - no sig. differences between treatment conditions at follow-up - no sig. reduction in analgesic use across all groups	Ter Kulie et al., 1994
Imagery	Not given	N = 40	- pressure pain thresholds	Yes	- pressure pain (induced by other, self, or other while imagining the pressure to be self-induced)	- elevated pain thresholds in self and imagery conditions (sig. differences between all conditions)	Lalouni et al., 2021
Hypnosis	‚Ideomotor movement– hypnotic phenomenon in which self-produced actions are attributed to an external source.	N = 6 highly hypnotizable	Neural correlates of active movements correctly attributed to the self or misattributed to an external source	Yes	- PET - hypnotic induction - deepening induction	- sig. higher activations in the PC in active movements attributed to an external source compared to identical movements attributed to the self	Blakemore, Oakley, & Frith; 2003
Spiritual and secular meditation, muscle relaxation	Not given	N = 83	- pain tolerance - headache frequency - mental and spiritual health variables	Yes	- cold pressor task	- greater decreases in the headache frequency, greater increases in pain tolerance, headache-related self-efficacy, daily spiritual experiences and existential well-being in spiritual meditation gr. compared to other groups	Wachholtz, & Pargament, 2005

Table 1. Overview of studies assessing autosuggestion and related phenomena. Abbreviations: A – autosuggestion, ACC – anterior cingulate cortex, AT – autogenic training, BOLD - blood oxygen level-dependent, exp – experiment, gr. – group, H – hypnosis, HI – headache index, NP – negative placebo, PP – positive placebo, PC – parietal cortex, PET – Positron Emission Tomography, PFC – prefrontal cortex, vmPFC – ventromedial prefrontal cortex, SEPs – somatosensory evoked potentials, QoL – quality of life, WLC - waiting list control* AT: postcentral BA 7 and BA 5, sup. frontal BA 6, inf. parietal (BA 40); Controls: postcentral BA 5, sup. frontal BA 6, inf. parietal (BA 40). **Table source:** Myga et al., *Exp. Brain Res.*, 2022, p. 385-386

In autosuggestion, we assume that repeating thoughts affirming that the body is in a different state (like feeling less pain) can change how we perceive sensations. However, simply focusing attention on the body can also influence how we perceive it afterward. For example, just by looking at the body, we can feel its temperature rise (Sadibolova & Longo, 2014), and visually attending to the body leads to producing analgesic effects during painful stimulation (Longo et al., 2009). Yet, these effects are not due to controlled thoughts or intentional imagery; they are more of unintended "side-effects" of directing attention to the body and do not represent a conscious or intentional change in perception. Moreover, directing attention or observing the body usually leads to similar results (like lowered tactile thresholds), with minimal control over sensory perception. In contrast, autosuggestion is distinct from these processes because it not only involves attention but also the conscious intention to change the perceptual state toward a specific goal. For example, autosuggestion might aim to reduce pain or enhance the feeling of a pleasant touch. In both cases, however, attention is equally directed to touch.

Autosuggestion shares conceptual overlap with mental simulation, as both are dynamic processes leading to perceptual state changes. Mental simulations are typically forward-directed (Springer et al., 2013), automatic (Markman et al., 2012), and improve with training (Decety & Ingvar, 1990). For instance, an experienced ice skater can perform more precise simulations of relevant movements compared to a beginners (Diersch et al., 2016). Within this context, mental simulations are often discussed under the umbrella of the forward model of motor control, where sensory outcomes of motor commands are compared to the actual consequences of movements (Miall et al., 1993) – they are usually fast, automatic, and rarely under an individual's direct control. Prediction errors, generated by discrepancies between expected and actual sensory inputs, are key in refining these simulations through learning (Friston, 2012; Kok & De Lange, 2015). However, few studies have explored the active control of mental simulations, contrasting them with autosuggestion, where intentional control over perceptual states is central.

Taken together, the concepts of autosuggestion, mental imagery, and mental simulation are related and may share important neural circuits and cognitive processes. All three involve recreating representations of states that are not currently perceived but rather created "offline". However, while mental imagery often refers to static states that are not necessarily future-oriented, autosuggestive processes should be dynamic and future-oriented. When participants simulate non-performed movements, mental simulations typically involve recalling a previous memory and do not conflict with ongoing sensory input (Kent & Lamberts, 2008). In contrast, autosuggestion is unique because it requires access to a dynamic, future-oriented process that is not always well-rehearsed and may require modifying or "overwriting" existing predictions.

2.1.2 Autosuggestion versus implementation intentions and reappraisal

We previously noted that autosuggestion is likely a process driven by the intention of achieving a specific change in a current perceptual state. It is in this regard relevant to distinguish autosuggestion from the concept of implementation intentions (Gollwitzer, 1999). Though both processes do contain a predefined situational trigger that evokes different perceptual states, the two processes do differ in their time scales and strategic components. Whereas in autosuggestion, individuals attempt to alter an existing perceptual state (e.g., biasing the unwanted experience of pain at the fingertip toward a desired perception), the process of implementation intentions involves planning a predefined response to a future-specific situation (i.e., intending to react in a goal-directed manner). For example, if someone aims to exercise regularly, they might set an implementation intention such as: *"If I wake up at 7:00 a.m., then I will go for a 30-minute run."* Here, the situational trigger (waking up at 7:00 a.m.) prompts a planned response (running), helping the individual overcome potential obstacles, such as procrastination or low motivation.

Thus, whereas the implementation intentions strategy focuses on overcoming potential *future* obstacles in transforming goals into action, autosuggestion seeks to achieve the desired goal in the *present moment*. In this way, implementation intentions may play a supportive role in learning to integrate autosuggestion into everyday life, such as setting a plan like, *"If I experience pain in my fingertip, then I will autosuggest a cooling sensation to alleviate it".*

Autosuggestion is closely related to the concept of reappraisal, although they differ in keyways. In appraisal, emotions are triggered not by the situation itself, but as a function of how the perceiver interprets it with respect to their emotional concerns. By reappraising, one biases emotions by changing appraisals (i.e., the emotional impact of the situation). Reappraisal involves altering these interpretations to change the emotional response to a situation. Essentially, by reframing how one thinks *about* an event, one can shift their emotional reaction (Uusberg et al., 2019). While this process shares similarities with autosuggestion, the two processes likely operate differently. For instance, muscle pain, experienced after heavy training at the gym, would be treated via autosuggestion by simply reducing the level of pain experienced. In contrast, reappraisal offers several ways to reinterpret the pain without necessarily reducing its intensity. One could choose to accept the pain and minimize its emotional and behavioral impact or even take it as a sign of physical progress. Rather than focusing on the experience itself, reappraisal changes the emotional significance of the experience and, consequently, reshapes the way it feels.

2.1.3 Autosuggestion versus heterosuggestion and hypnosis

Hypnotic suggestion and heterosuggestion are closely related to autosuggestion, but they differ in key aspects (see **Box 1**). In both hypnotic suggestion and heterosuggestion, an external individual, such as a trained experimenter, provides instructions designed to alter subjective experiences and behaviors. Over the past several decades, researchers have employed hypnotic induction as one of the ways to modify top-down control processes (Barber & Calverley, 1964; Jamieson & Burgess, 2014; McGeown et al., 2009; Rainville et al., 1997). Hypnotic suggestion has been reported to be effective in a wide range of domains, including temporary pain relief (Crasilneck & Hall, 1973; Sacerdote, 1962), inducing motor inhibition in hysterical conversion paralysis (Cojan et al., 2009), suppression of automatic processes such as Stroop interference (Raz et al., 2002, 2005), modulation of color perception (Kosslyn et al., 2000), or enhancing the rubber hand illusion in highly susceptible individuals (Fiorio et al., 2020).

For instance, Fiorio et al. (2020) examined how hypnosis affects the sense of body ownership during the rubber hand illusion (RHI) in participants with varying levels of hypnotizability. The RHI is induced by synchronous stimulation of a rubber hand and the real hand of the participant, which creates the illusory perception of ownership of the rubber hand, whereas asynchronous stroking disrupts this effect (Botvinick & Cohen, 1998). This illusion is typically accompanied by proprioceptive drift, where individuals perceive their real hand to be closer to the rubber hand than it actually is. The experiment was run both with and without hypnotic induction. Both highly and less hypnotizable participants reported greater ownership of the rubber hand during synchronous stroking, but only highly hypnotizable individuals showed an increased proprioceptive drift under hypnosis. Similarly, Walsh and colleagues (2015) showed higher proprioceptive drift in participants scoring higher on the hypnotic suggestibility scale. This suggests that in highly hypnotically susceptible individuals, hypnosis could facilitate the recalibration of body ownership.

A key distinction between hypnosis and autosuggestion lies in the diminished sense of intention and control occurring in hypnosis, which is indeed in contrast with the self-directed nature of autosuggestion. Even in self-induced hypnosis, individuals often report reduced control over their bodily states. Hypnotic states are typically characterized by feelings of involuntariness and a disrupted sense of agency, where participants experience a lack of control over their own actions (Polito et al., 2015). This experience of diminished agency, often described as "involuntariness bordering on compulsion" (Barber, 2008), has remained central to the definition of hypnosis. The phenomenon has even been referred to as "conviction bordering on delusion" (Barnier et al., 2008), and this exaggerated sense of involuntariness is considered to be a *hallmark of hypnotic experiences*.

For example, in a study by Blakemore and colleagues (2003), hypnosis was used to induce delusions of alien control in healthy participants. During the experiment, participants were subjected to four conditions while in a hypnotic state: 1) *Active movement* (the participant actively lifted their arm), 2) R*eal passive movement* (the experimenter lifted the participant's arm using a pulley attached to the wrist), 3) *Deluded passive movement* (participants were told that their arm would be lifted by a pulley, but no pulley was used), and 4) *Rest condition*. Highly suggestible participants reported that their arm movement felt involuntary and unintentional during the *deluded passive movement* condition, even though the movement had been self-generated. In the *active movement* condition, on the other hand, they correctly identified such movements as self-generated. The study used PET to examine the neural bases of these feelings of passivity during the two conditions. Results indicated that the cerebellum and parietal operculum showed significantly greater activation in the *deluded passive movement* condition compared to the *active movement* condition. This is particularly noteworthy because usually, the parietal operculum is more active during passive movements compared to active ones in general (Mima et al., 1999). Such findings suggest a different neural treatment of identical physical movements depending on whether they are attributed to oneself or perceived as being controlled from the outside.

The subjective feeling of self-control, along with the actual ability to exert control over oneself, is a key advantage of autosuggestion compared to hypnosis and heterosuggestion. Autosuggestion does not only involve the recipient's willingness and awareness to influence their own cognitive state but it can also be practiced independently, without the need for intervention from a therapist (Schlamann et al., 2010). In contrast, heterosuggestion (including hypnosis) is a social process: it depends upon the relationship between the person and the individual making the suggestion. Autosuggestion eliminates this dynamic: the person acts as both operator and subject, making it more accessible for long-term use when successful. Given these differences, it is clinically and practically important to assess whether self-directed mental changes through autosuggestion can be as effective as changes initiated by another person.

2.1.4 Autosuggestion versus placebo

Placebo refers to an inactive treatment or a non-specific component of a treatment that is administered to alleviate symptoms or illness, despite lacking any direct therapeutic effect (Shapiro & Shapiro, 2000). Placebo is a unique form of heterosuggestion, influenced not only by the other individual but also by the situational and social context (Miller & Kaptchuk, 2008) and the person's previous experiences (Colloca & Benedetti, 2006). Factors strongly predicting the success of the placebo responses are externally evoked expectations (i.e., specific cognitions about the probability of future events (Rief et al., 2015), and consequently formed beliefs regarding the effects of treatment (Beauregard, 2007). These expectations typically arise from external cues such as medical symbols (e.g., white coat, the syringe; (Petrie & Rief, 2019), and can be reinforced by the inner desire for relief (Tracey, 2010). The placebo effect, therefore, works at the crossing point of social suggestion, personal history, and cognitive belief systems.

Expectations about a specific cue leading to a specific outcome are learned over time (Petrie & Rief, 2019), and extend beyond simple beliefs about whether a treatment will or will not work. People's expectations are also influenced by the value they attribute to a treatment – for instance, a red pill, perceived as a more expensive one may be more effective than a blue pill, perceived as a cheap one (Tracey 2010). Placebo responses are complex phenomena shaped not only by expectations and beliefs but also by personality and psychological traits (Tracey, 2010). A crucial aspect of this is self-efficacy, as highlighted by Bandura (Bandura, 1977). Self-efficacy refers to an individual's belief in their capacity to influence the outcomes in their life. In the context of autosuggestion, this means that only when one believes in their capacity to achieve certain goals – such as inducing desired perceptual or mental states through autosuggestion – will they be motivated to take the necessary steps. This includes activating the cognitive processes required to effectively implement autosuggestion.

To date, the extent to which these factors influence autosuggestion remains largely unexplored. Most placebo research has focused on responses to painful stimuli (e.g., Montgomery & Kirsch, 1996). For example, Wager et al. (2015) investigated the effects of a placebo cream applied to reduce pain sensations on the wrist. In the *baseline* condition, participants received both intense and mild shocks and rated the pain intensity. In the *placebo* condition, a cream was applied to their wrists. Half of the participants were told the cream would reduce, but not eliminate, the pain (placebo group), while the other half were informed that the cream had no pain-relieving properties (control group). After half of the trials, the instructions were reversed, allowing each participant to serve as both: a control and an experimental subject. Pain ratings for intense shocks were significantly lower in the placebo group compared to the control group, though, no differences were observed for mild shocks. Interestingly, the size of the reported pain reduction was directly related to decreased activity in brain areas associated with the sensory processing of pain during shock in the placebo group, as measured by fMRI. Furthermore, placebo analgesia was correlated with increased activation in prefrontal brain areas, reflecting a cognitive modulation of pain perception. These findings demonstrate that external cues, such as the application of a placebo cream, can effectively alter cognitive, sensory, and emotional experiences of pain (e.g., Fiorio et al. 2012).

It would be relevant to consider whether one of the possible mechanisms that drive the placebo response could be explained by autosuggestion (Jakovljevic, 2014). In that perspective, ideas coming from a professional are not only believed and internalized by the patient but can be also reinforced through internal thought repetition. This self-reinforcement, together with the expectations and beliefs formed around the procedure's success, could constitute a starting point for autosuggestion. For example, Staats and colleagues (1998) conducted an experiment on pain perception, that is related to both autosuggestion and placebo effects. Participants were asked to keep the dominant hand in iced water (approximately 1 °C) for as long as possible or until experiencing pain. Participants were divided into groups receiving positive or negative suggestions about the experience of cold immersion and instructed to mentally reiterate this information during the task. The positive placebo group received encouraging suggestions and demonstrated higher pain thresholds, greater tolerance, and increased endurance compared to their baseline immersion and the other groups during subsequent immersion trials. Additionally, these participants experienced reduced anxiety and worry, along with an enhanced ability to cope with pain. Conversely, the negative placebo group exhibited opposite outcomes, with reduced pain tolerance and greater discomfort.

The mental repetition of the given suggestion, or "covert reiteration" aligns with the principles of autosuggestion, even though the authors referred to a placebo effect. However, the study did not distinguish between the effects of receiving the initial suggestion and those of reiterating it, thus, future research could isolate both the independent roles played by suggestion and autosuggestion in these outcomes. This differentiation could provide a clearer understanding of the overlap between placebo responses and autosuggestion.

2.2 Discussion and future directions of autosuggestion research

Building on existing evidence and addressing gaps in the literature, we aimed here to develop a functional definition of autosuggestion. We defined autosuggestion as the *instantiation and reiteration of ideas or concepts* by *oneself* aiming to *actively bias one's own perceptual, brain or interoceptive states, as well as the valence of perceived sensations. This reiteration takes a verbal/linguistic form (internally or out loud) and may be reinforced by employing imagery. Autosuggestion may take both forms: implicit and explicit.* We assume that other cognitive strategies, such as mental imagery or mental simulation, may be implemented in the process of autosuggestion, although these should be controlled for, in carefully designed studies. This working definition distinguishes autosuggestion from related phenomena like heterosuggestion, hypnosis, mental imagery, and mental simulation (see **Box 1**).

Based on the current evidence reviewed on autosuggestion, we conclude that empirical evidence on autosuggestion remains limited. Consequently, key questions – such as identifying the neural correlates of autosuggestion or determining its effectiveness in modulating perception, remain largely unanswered. This literature review of available evidence on autosuggestion, together with an evaluation of experimental methodologies, highlights the need for further research, in particular in distinguishing autosuggestion from related concepts like mental imagery, simulation, hypnosis, and placebo.

Potential brain networks that could be influenced by autosuggestion include sensory cortices, the insula, and cognitive control networks. However, flaws in prior experimental designs – such as inadequate control conditions or the failure to distinguish autosuggestion from related processes like attention or placebo effects – have been noted. Building on this critique, we propose an alternative experimental approach to more effectively examine the cognitive mechanisms underlying autosuggestion (see **Figure 2**). This approach aiming to isolate autosuggestion by employing more rigorous controls and carefully designed tasks that distinguish it from overlapping phenomena, has been implemented in the studies presented in this thesis.

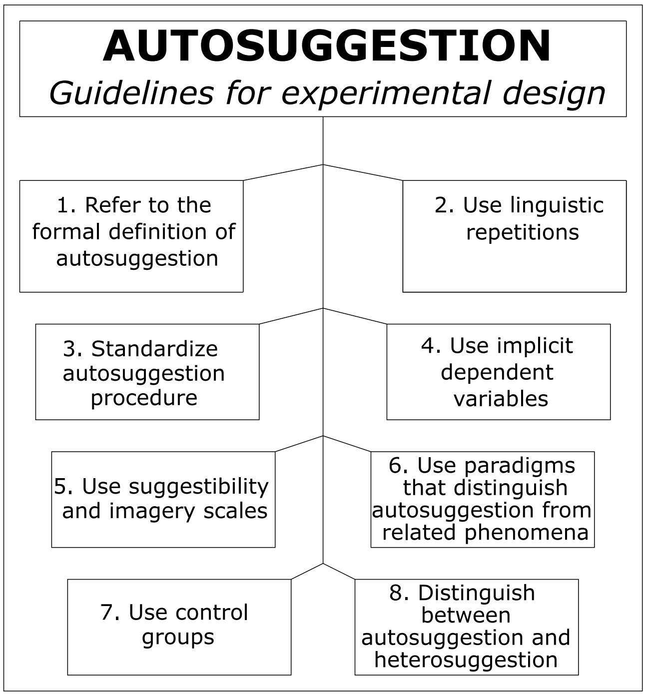

Figure 2. Directions for experiments on autosuggestion. For detailed description see in the text below. **Figure source:** Myga et al., *Exp. Brain Res.,* 2022, p. 391

The following section, grounded in the theories and experimental methodologies reviewed above, offers eight concrete suggestions for successfully integrating an autosuggestion condition into experimental research designs. While these guidelines offer valuable insights, they are not rigid or exhaustive. These recommendations may not apply universally, because some experimental designs or certain populations may require specially tailored procedures or setups. Our intention here is to provide an initial framework of necessary steps and preparations to facilitate the successful design of an autosuggestion experiment. Our studies aim at validating these guidelines, which are further elaborated upon in the General Discussion chapter.

First, any experimental approach studying autosuggestion should adhere to a formal definition of the term (see **Figure 2, Point 1** and **Box 1**). This precision allows for explicit communication between researchers and readers as to exactly what phenomenon is being investigated and facilitates the meaningful comparison of the effectiveness of various methodologies. In all our experiments, we ensured that the concept of autosuggestion adhered to the proposed definition.

Second, any experimental approach investigating autosuggestion should incorporate a linguistic repetition of the desired states that the person aims to experience (see **Figure 2, Point 2**). This linguistic repetition can be spoken out aloud or internally (in the mind's ear). The phrases used should follow the criteria: 1) They should reference to the self, using 'I', 2) They should state the desired outcome in the present tense as if it were already a reality, 3) They should be concise, and 4) They should be framed in positive terms, avoiding negations (e.g., using 'I am okay' rather than 'I am not in pain'). These linguistic constructions ensure that suggestions are easier to apply by clearly specifying the recipient, being easy to focus on, and minimizing potential confusion. In our experiments, all participants were presented with the phrases they could repeat and were briefed on the rationale behind each example provided.

Third, the procedure of inducing autosuggestion in an experimental setting should be standardized to minimize variability and increase the consistency of the results. Therefore, future experiments should favor structured autosuggestion over more open-ended approaches (see **Figure 2, Point 3**). By "structured" we mean that a uniform type of linguistic repetition and autosuggestion procedure – such as consistently using or excluding imagery and utilizing predefined statements – should be employed across all participants. To achieve this goal, participants in our experiments were instructed to perform their autosuggestion in a standardized manner and according to linguistic guidelines stated above.

Fourth, the dependent variable used in the experimental design to measure autosuggestion should be as implicit as possible, meaning that the brain or physiological state measured differs from the one the participants are autosuggesting (see **Figure 2, Point 4**). This is critical, as it allows for a clearer delineation between the autosuggestion process and participants' compliance with the experimenter (i.e., demand characteristics; Orne, 1962). If this is not entirely possible, at a minimum, measures that cannot be voluntarily manipulated by participants should be included, such as recording physiological correlates without providing any feedback (e.g., EEG, fMRI). We aimed to follow this principle consistently throughout our studies. In Studies 1 and 2, we tested participants on a variable orthogonal to the variable of interest, using the established association between tactile intensity perception and frequency. Study 3 indirectly evaluated autosuggestion by measuring the effects of autosuggestion on the crossed hands deficit in a temporal order judgment task. Lastly, Study 4 employed adaptation aftereffects to quantify the effects of autosuggestion.

Fifth, suggestibility scales (e.g., Multidimensional Iowa Suggestibility Scale (MISS); Kotov et al. 2004) and mental imagery scales (e.g., VVIQ; Marks, 1973) should be used in parallel when investigating the effects of autosuggestion (see **Figure 2, Point 5**). Using these scales makes it easier to study the generalizability and some of the key abilities necessary for the successful use of various types of autosuggestion, such as high suggestibility and strong mental imagery abilities, and sheds light on some of the mechanisms involved. They can also help in the selection of appropriate participants for autosuggestion interventions in clinical populations. Also, it would be of interest to examine participants' beliefs about their own ability to bring about desired outcomes through autosuggestion, to be able to test whether there is a correlation between what a person believes and their effectiveness. Although our studies did not specifically target interindividual differences in suggestibility and imagery skills, and our sample sizes were too small for correlational analyses, we did include these measures, which could be useful for future follow-up experiments.

Sixth, experiments should attempt to differentiate between autosuggestion, attention, and mental simulation (see **Figure 2, Point 6**). One way to control for attention is to have the direction of the effect reverse in different conditions, since attention typically alters the attended sensation in the direction of enhancement, which we have implemented in our Studies 1 and 2. In cases where direct comparison was not feasible, we incorporated follow-up questionnaires that also explored aspects of attentional processes. According to the definition of autosuggestion (i.e., its deliberate effort to influence ongoing experiences in the present moment), our studies distinguished autosuggestion from mental simulation – a mental process typically automatic and beyond the individual's conscious control.

Seventh, as we have done in all our studies, it is necessary to include one or more control groups or conditions in an experiment to be sure that the effects observed are the result of the manipulation and not some external factors (e.g., training effects, time; Makin & Orban de Xivry, 2019). The use of appropriate control conditions, for example, comparing autosuggestion with imagery, would help to delineate more precisely which techniques are more efficacious in eliciting specific experiences, providing valuable insights for clinical interventions (see **Figure 2, Point 7**).

Eighth, any experimental approach that investigates autosuggestion should specify whether it focuses on autosuggestion or heterosuggestion (see **Figure 2, Point 8**). It is crucial to identify which agent is responsible for inducing the change – the participant or the experimenter. If written instructions are presented on-screen, researchers should clarify whether participants perceive these instructions as their own (for instance, if they can choose their own linguistic repetitions or incorporate the instructions personally) or as directives imposed by the experimenter. Even subtle distinctions can significantly impact the results of the experiment and may engage different cognitive mechanisms. To achieve this goal, we ensured clarity in describing our procedures and the phenomena under investigation. In this chapter, I have presented a comprehensive review of the literature on the cognitive phenomenon of autosuggestion. The integration of the findings supports the conceptual starting point that top-down mechanisms, such as autosuggestion and related phenomena like placebo (Blair, 1965), autogenic training (Kanji, 2000), and imagery (Fardo et al., 2015), can induce changes on behavior, cognitive, and neural levels, by altering subjective experience. Given its considerable potential benefits, autosuggestion has not yet been rigorously studied in the scientific setting. Therefore, the next phase of this thesis will focus on addressing specific research gaps and advancing our understanding through robust experimental methodologies.

Moving forward, the thesis will delve into experimental investigations aimed at systematically exploring the effects of autosuggestion on various perceptual and cognitive domains, including tactile perception, body representation, and emotion perception, while also comparing these effects to related phenomena such as placebo and mental imagery. If the positive effects of autosuggestion are scientifically validated, it could pave the way for the development of a new field of self-directed treatments.

In the following chapter, I will present our first empirical study, which investigates whether autosuggestion can change tactile perception towards a stronger or weaker feeling than the actual stimulus. This is the first of a series of studies I will discuss, we designed using implicit measures.

Chapter 3

Study 1: How the inner repetition of a desired perception changes actual tactile perception

This chapter is based on content originally published in "Myga, K. A., Kuehn, E., & Azanon, E. (2022). Autosuggestion: a cognitive process that empowers your brain?. *Experimental Brain Research*, 240(2), 381-394. https://doi.org/10.1007/s00221-021-06265-8". While most of the chapter has been extensively rewritten, a few sections, including text and figures, may be identical to the published work to ensure the accuracy and integrity of the original findings.

3.1 Introduction

The concept of autosuggestion, introduced by Émile Coué, has long been central to self-help literature (e.g., Clark, 2024; Fuller, 2010; Hay, 2004; Leaf, 2013; Peer, 2009). In the General introduction, we defined autosuggestion and contrasted it with other top-down strategies. We also noted the absence of a consistent theoretical and methodological framework in studies on autosuggestion. To address these limitations, in this study, we test the effects of inner reiteration of thoughts in modulating tactile perception while minimizing the impact of demand characteristics. For this aim, we developed an experimental paradigm that uses implicit measurements (see below).

In the present study, autosuggestion (or self-suggestion) is defined as the reiteration of specific thoughts or statements (e.g., "The touch I receive feels very strong"), with the intent of actively influencing one's own perception (Myga et al., 2022). While alternative definitions of autosuggestion exist (Kathyayani et al., 2022; Shilpa et al., 2020) this definition aligns closely with Émile Coué's original concept of autosuggestion (Baudouin, 1923). According to Coué, individuals internally repeat suggestions using inner speech and/or acoustic-verbal imagery – they are essentially "talking" to themselves in their minds. It is important to note that, despite instructing participants to use autosuggestion as stated in its definition, individuals' specific cognitive processes during the experiment cannot be determined with certainty.

In Study 1 we addressed the question of whether autosuggestion could influence participants' somatosensory perception at the finger. Specifically, participants were asked to repeat suggestions that the perceived intensity of a given vibrotactile stimulus felt either very weak or very strong. However, they were then asked about the perceived frequency of the touches. By posing this question orthogonal to the manipulated variable (i.e., tactile intensity), we aimed to minimize response bias. Specifically, by focusing participants' attention on frequency perceptions, the manipulated variable was obscured from their awareness due to the task demands, thereby maintaining the implicit nature of the measurement employed. In this respect, we made use of the known interaction between vibrotactile intensity and frequency perception, known as the "Békésy effect" (von Békésy, 1959); see also (Morley & Rowe, 1990; Roy & Hollins, 1998). To be precise, increasing the intensity of vibrotactile stimuli while keeping the frequency constant can lead to either an increase or a decrease in perceived frequency. Although the direction of this effect varies among individuals, it generally remains stable for each person, making it a suitable method for investigating the effects of autosuggestion in a within-subject design. These effects are classified as either "positive association" (where an increase in intensity leads to an increase in perceived frequency) or "negative association" (where an increase in intensity results in a decrease in perceived frequency).

During the experiment, participants were presented with two sequential tactile vibratory stimuli. They were instructed to use autosuggestion to modulate the perceived intensity of the first touch, by repeating the thoughts that the touch feels strong (Experiment 1) or weak (Experiment 2), and they responded whether the second touch had a higher or lower frequency compared to the first one. Using a similar sequential paradigm, Morley and Rowe (1990) found that the majority of participants in their study showed a "positive association". We therefore initially targeted participants showing a positive association (Experiment 1). It is important to note that no specific preferences were made for either group, as we anticipated comparable results.

In total, we conducted three experiments: Experiments 1 and 2 introduced a novel paradigm to investigate the effectiveness of autosuggestion in either increasing (Experiment 1) or decreasing (Experiment 2) the perceived intensity of tactile stimuli, indirectly assessed through the perceived frequency of those stimuli. The third experiment explored the potential influence of language on the effect of autosuggestion. In Experiment 3, the response options were altered from "low" and "high" to "slow" and "fast" to minimize cognitive associations between "high amplitude" and "high frequency" (and vice versa). Collectively, these three experiments offer a first systematic evaluation of how autosuggestion affects the perception of touch on the fingers.

3.2 Experiment 1: autosuggestion strong

Experiment 1 aimed to determine whether autosuggestion could *increase* the perceived intensity of touch on the reference finger. Participants were instructed to "Feel the touch on the left finger as strongly as possible" through the use of autosuggestion. For that, they were asked to repeat thoughts such as: "The touch feels very strong", "I feel the touch very, very strong". Following this, they were asked to report whether the frequency on the comparison finger was higher or lower than that on the reference finger.

3.2.1 Materials and methods

Participants

To date, no previous study exists on the effect of autosuggestion on tactile perception based on which we could reliably calculate a desired sample size. The sample size calculation was thus based on the results provided by Fardo et al. (2015). They used imagery as an experimental manipulation to increase or decrease painful sensations. The sample size was calculated based on the effect size of participants' subjective responses to the intensity of painful stimuli on a visual analog scale, either while imagining a wound at the stimulation location (*facilitation* condition) or without any imagery (*baseline* condition).

Based on the results depicted in Figure 2a of their study, the mean and SD for the *facilitation* condition (M = 7.45, SD = 1.60) and the mean of the *baseline* condition (M = 6.60) were extracted. Using the Matlab 'sampsizepwr' function for a repeated measures design, with a power set to 0.80, a required sample size of 30 participants was obtained.

Based on this number, we tested 33 participants. One participant reported difficulties understanding the task during the practice session and did not proceed with the experiment. Additionally, one participant could not complete the study due to fatigue, resulting in their dataset being discarded. Among the remaining 31 participants, 10 failed to meet the goodness-of-fit threshold ($R^2 \geq .40$) in one or both conditions. Note that for most participants, low goodness-of-fit was driven by a lack of perceptual intensity-frequency coupling (i.e., neither positive nor negative association, "flat trend"). Two participants showed a negative association (with negative just noticeable difference mean values in both conditions). Given the low number of participants with a negative association (n = 2) and their exclusion from the initial sample of interest, these participants were removed from the analysis. A total of 19 participants showing a positive association trend were analyzed (8 females, M age = 28.42, SD = 3.20, 18 right-handed, M = 92.94, range: 11.11 – 100; as assessed by Edinburgh Hand Inventory; Oldfield, 1971). All participants gave written informed consent and were paid for their participation. All methods were performed following the guidelines and regulations set out by the ethics committee (ethics code 01/19) of the Otto-von-Guericke University Magdeburg and in compliance with guidelines defined by the Leibniz Institute for Neurobiology (LIN) in Magdeburg, where testing took place.

Stimuli

Tactile stimuli were administered using solenoid tappers (MSTC3-10M, M & E Solve), attached to participants' right and left distal pads of index fingers. Each stimulus, a square wave lasting 500 ms, generated a vibrating tapping sensation. Stimuli were presented using MATLAB version R2015a (MathWorks) and Psychtoolbox, version 3.0.11 (Brainard, 1997; Kleiner et al., 2007). The same stimuli were used in this and subsequent experiments.

Procedure

The day before the experiment, participants received a brief document with an introduction to autosuggestion and an outline of the tasks involved. This information was provided to participants for two main reasons: first, to familiarize them with the phenomenon of autosuggestion before their participation, and second, to encourage motivated participation to take part in the experiment. It was assumed that willingness or intention to induce specific perceptual states was a prerequisite for performing autosuggestion (see Myga et al., 2022 and Chapter 1). Participants were also given the option to cancel their participation if they were uncomfortable with the experimental paradigm before it started.

On the testing day, participants began by completing a consent form and the Multidimensional Iowa Suggestibility Scale, which is a 5-point Likert scale (MISS, Kotov et al., 2004). The subscales used included Sensation Contagion (SC), Physiological Reactivity (PHR), Psychosomatic Control (PSC) subscales, as well as an overall score combining these subscales. The purpose of administering these suggestibility scales was to assess participants' suggestibility concerning somatosensation and bodily experience, as suggested in Chapter 2 (see **Figure 2, Point 5**).

Participants were seated in front of a 24.4-inch monitor, with an eye distance of about 56 cm away from the screen. After adopting the most comfortable seating position, solenoid tappers were attached to the participants' right and left index fingers (see above).

The experiment was divided into four parts, where each was explained to participants before it started, as follows:

Frequency-intensity discrimination training session

The frequency-intensity discrimination training was designed to familiarize participants with the task and clarify the distinction between tactile frequency and tactile intensity. To illustrate these concepts, the experimenter first demonstrated on the dorsum of her left hand, how vibrotactile intensity and frequency were defined in the study. Specifically, the experimenter used her right index finger to apply touches, imitating the up-and-down movements of the vibrating stimulus in an exaggerated manner. For intensity, the experimenter repeatedly poked her hand with varying pressure by making larger or smaller movements. To represent the dimension of frequency, the experimenter delivered multiple consecutive pokes (approximately five in a row) at varying speeds. All participants confirmed their understanding of the differences between vibrotactile intensity and frequency before proceeding with the next task.

The practice session comprised two blocks, each containing eight trials. In each block, from trial to trial, the intensity of the stimulation rose step by step, equally on both fingers from level 2 to level 9 in that order (of a 16 V amplifier with 10 as a maximum value). Frequencies for the paired stimuli were randomly selected from the combinations: 10 – 30 Hz, 30 – 10 Hz, 20 – 40 Hz, and 40 – 20 Hz. The first value corresponded to the frequency delivered to the reference finger, and the second value corresponded to the frequency delivered to the comparison finger. Each stimulus lasted 500 ms, separated by a 1-second interstimulus interval (ISI). Participants were instructed to indicate whether the touch on the comparison finger (right index) felt higher or lower in frequency than on the reference finger (left index). This approach trained participants to focus on frequency while disregarding intensity. Responses were made by lifting the toes of the right foot for "higher" or the heel for "lower". If a participant lifted their foot outside the designated response window, an error message appeared on the screen for 2 s. Although responses were not timed, participants were encouraged to respond as quickly and as accurately as possible. Following each response, feedback was provided: "Correct" or "Wrong." Participants could repeat the practice session until they demonstrated successful task performance. Most participants made five or fewer errors out of 16 in the final practice session, with the group averages as follows: Exp 1 = 2.25 errors; Exp 2 positive trend = 2.75 errors; Exp 2 negative trend = 1.22 errors; Exp 3 = 1.6 errors. Three participants (n = 1 in Exp 1, and n = 3 in Exp 3) showed 6 to 7 errors, and n = 1 mistaken the response mapping in Experiment 1 (12 errors). Despite these difficulties in perceiving the 20 Hz threshold differences, they were allowed to proceed with the experiment since they demonstrated a clear understanding of the task through verbal communication. Note that the exclusion of these participants (2 in Exp 1 and 3 in Exp 2) gives a similar pattern of results in Experiments 1 and 2.

Training session of the main experiment

Following the frequency-intensity discrimination training, participants were trained on the main paradigm which closely resembled the training but had a key difference: the intensity of the touches on the reference finger was held constant at level 5 (with 10 being the maximum on a 16 V amplifier). In contrast, the intensity on the comparison finger varied across seven levels, ranging from 2 to 8 units. The frequency of stimulation was maintained at a constant 30 Hz for both fingers, with a stimulus duration of 500 ms (16.67 ms for the pin up and 16.67 ms for the pin down). The choice of the used frequency was based on the study by Morley and Rowe (1990). During this phase, no feedback was provided to the participants. Participants performed a total of 70 trials and had one untimed break in between.

Autosuggestion training

Next, participants were trained in performing autosuggestion. They were first asked to review the information sheet they had received the previous day, which provided a definition of autosuggestion, its relevance to the experiment, and detailed instructions on how to apply it. Then, the experimenter removed the tactile stimulator from the comparison finger, so participants received stimulation only to their reference finger. The training began with participants receiving five tactile stimuli (30 Hz, 500 ms, intensity level 5), separated by a 1 s ISI, to familiarize them with the same type of stimulation they would experience throughout the session. Afterward, participants completed 10 trials. In each trial, they first received three consecutive touches, which they were instructed to passively experience without any cognitive modulation. This was followed by a 5-second period during which a fixation cross appeared on the screen. During this time, participants were asked to autosuggest that the next three touches would feel as strong as possible. After each trial, participants used a visual analog scale to rate how successful they believed they were in perceiving the autosuggested touches as stronger compared to the initial, non-autosuggested touches. To facilitate this internal comparison, the intensity of stimulation remained constant throughout, and participants were informed of this consistency.

Main experimental session (testing the effects of autosuggestion versus baseline)

Participants placed their hands palm upwards on a table while being seated, with hands spaced about 15 cm apart. There were two conditions: *autosuggestion* and *baseline*, presented in an ABBA design (the first condition counterbalanced across participants). During the tactile stimulus presentation, only instructions were displayed on the screen, which was otherwise kept black to minimize visual distractions and to ensure full focus on the tactile task. Before the experiment began, participants rated their belief in their ability to change the perception of touch intensity on their reference finger using a visual analog sliding scale. This expectancy measure ranged from 0 (not at all) to 100 (very convinced) to assess their confidence in influencing touch perception. In the autosuggestion blocks, participants were also asked to rate their belief in the effectiveness of their autosuggestion (self-efficacy) every 14 trials (a total of 7 times). This repetitive self-efficacy assessment aimed to maintain participants' attention on the perceived outcomes of their autosuggestion efforts.

In the *autosuggestion* condition, participants were first asked to create thoughts that the upcoming touches on the reference finger will be very strong for one minute and then every 15th trial for another period of 10 s (7 times throughout the session). Specifically, they were instructed to internally repeat the desired outcome (e.g., "The touch feels very strong') while avoiding the use of negations (e.g., "The touch is not weak"). Additionally, they were asked to avoid creating images in their mind's eye as much as possible to prevent the influence of mental imagery. Each trial was separated by a 2-second intertrial interval (ITI), during which participants were asked to continue repeating their suggestions. During each trial, they first received a 500 ms tactile stimulus on the reference finger (i.e., the focus of autosuggestion), followed by a 1-second ISI, and then a 500 ms stimulus on the comparison finger, always in that order (see **Figure 3**). Participants were asked to indicate via a footpress whether the touch on the comparison finger felt higher or lower in frequency than the touch on the reference finger, while explicitly ignoring the intensity. It was unknown to them that the frequency of touches on both fingers was always the same (30 Hz). The intensity of the stimulation on the reference (autosuggested) finger was also constant (level 5). Only the intensities on the comparison fingers varied between levels 2 to 8 (where 10 is the maximum) of a 16 V amplifier. Participants were allowed one untimed break per block. Additionally, a sham skin conductance device was attached to their reference finger. They were told that the experimenter could calculate whether and to what extent their autosuggestion was effective based on these physiological measurements, though no such measurements were actually taken. This sham device, alongside the experimenter wearing a white coat in this and all the experiments for Study 1 and 2, was used, with the expectation that participants would feel the seriousness of the procedure, fostering participant motivation and encouraging increased effort during the *autosuggestion* condition.

The *baseline* condition closely mirrored the *autosuggestion* condition, with one key difference: instead of mentally repeating thoughts to influence their perception, participants were simply instructed to attend to the tactile sensations. In both conditions, participants were instructed to focus their attention equally on each touch, as the task required them to compare their perceptions of the two touches. Specifically, they were asked to first focus on the reference (or autosuggested) touch, followed by the comparison touch. In the middle of the experiment – just before the third block – the experimenter swapped the tactile stimuli solenoids between the two fingers. This aimed to balance across conditions any possible differences in the strength or qualia of the stimuli applied to each hand driven by potential physical differences between the two solenoids.

Upon completing all four blocks of the main experiment, participants indicated on an analog slide scale, how strongly they believed they had succeeded in perceiving the touch on their left finger as stronger during autosuggestion (final self-efficacy measure). We intentionally delayed the immediate disclosure of the fact that the skin conductance device was not measuring participants' performance success in their autosuggestion. This was done because concurrent studies using a similar autosuggestion and placebo procedure were ongoing. To preserve the credibility of the experimenter and avoid undermining these parallel studies, the full disclosure was postponed until after all data collection had been completed.

To mask the auditory noise generated by the tappers, participants listened to white noise during each task. Overall, the entire procedure lasted between 2.5 to 3 hours.

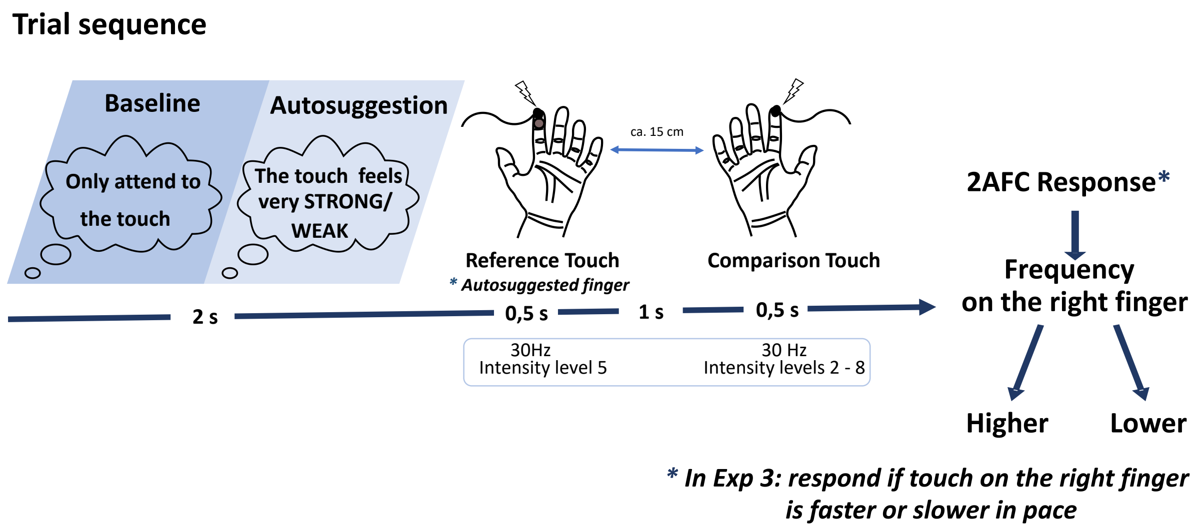

Figure 3. Overview of the main experimental session. Participants placed their hands palms upwards, with hands about 15 cm apart from one another. In both *baseline* and *autosuggestion* conditions, participants received two touches: first on the distal pad of their left index finger (reference) followed by the touch on the distal pad of their right index finger (comparison). After the second touch was delivered, participants were asked to indicate whether the touch on the comparison finger was higher or lower in frequency (Experiments 1 and 2) or faster or slower in pace (Experiment 3) than the touch on the left reference finger, while ignoring the intensity. Before the touch delivery (during the intertrial interval, ITI of 2 s), in the *autosuggestion* condition, participants autosuggested that touch on the left, reference finger felt as strong (Experiment 1) or as weak (Experiments 2 and 3) as possible. In the baseline, participants were instructed only to attend to both incoming touches. The frequency on both fingers was always the same (30 Hz) and only intensities on the right index finger varied across 7 intensities. The intensity on the left finger was stable and set out to the intensity of the middle range of those on the right finger. An additional

sham device to monitor skin conductance was attached to the reference finger in the main experimental part, to motivate participants (see the description of the Main experimental session above). **Figure source:** Myga et al., *Sci. Rep.*, 2024, p. 3072

Analyses

The analyses were conducted using MATLAB version R2015a (MathWorks). Participants' responses were extracted as the proportion of responses where the comparison stimulus was judged as higher in frequency. These responses were then fitted as a function of the comparison stimulus intensity using a logistic function. An unbiased participant would be expected to produce a flat line (all responses centered around 50%) when comparing the frequency across the two hands, as the frequency was constant and identical to both fingers throughout the experiment. However, given the above-mentioned perceptual associations between intensity and frequency, it was anticipated that most participants' logistic functions would display either an upward trend ("positive association") or a downward trend ("negative association"), reflecting the influence of stimulus intensity on their frequency judgments.

To determine whether a participant produced a rising or decreasing psychometric function, the just-noticeable difference (JND) was calculated as the semi-interquartile range. However, it is important to note that in this context, the JND does not serve as a measure of precision. Rather, larger or smaller JNDs reflect the strength of the "perceptual illusion" between intensity and frequency, rather than the participant's ability to precisely discriminate between the frequency of stimuli (which is always identical). A positive JND value indicates a rising psychometric function (i.e., the participant exhibited a "positive association" between intensity and frequency). Conversely, a negative JND value signifies either a decreasing psychometric function (indicating a "negative association") or a curve that is generally shifted upward with a slight rise. Both the JND values and visual inspection of the curve's trend were used to classify each participant's psychometric function as rising or decreasing.

Additionally, only data that met a goodness-of-fit criterion ($R^2 \geq .40$) were included in the final analysis. The primary dependent variable, the point of subjective equality (PSE), was extracted, representing the comparison stimulus intensity at which participants perceived the two stimuli as having the same frequency.

Due to the sample size being smaller than required to reach a predefined effect size, we used the non-parametric Wilcoxon Signed-Ranks test to determine whether differences across conditions were statistically significant, using the Exact Tests™ software (Mehta & Patel, 2011). The Wilcoxon Signed-Ranks test serves as the non-parametric equivalent of the paired sample t-test (Field, 2013). The Exact Tests™ is a statistical package integrated within the Statistical Package for the Social Sciences software (SPSS). This method is particularly useful for making reliable inferences when data are not normally distributed, sparse, or heavily tied, or when sample sizes are small (Mehta & Patel, 2011). The algorithms used by the software compute exact p-values for hypotheses testing, based on the exact distribution of the test statistic. Consequently, these tests do not rely on assumptions regarding the normality of the data. The significance level for determining a significant effect was set at alpha < .05. Corresponding Wilcoxon effect sizes (r) were calculated using the following equation:

$$r = Z/\sqrt{N}$$

where Z is the z-score, and N is the total number of observations over the two conditions (Kotov et al., 2004). Expectancy ratings and final self-efficacy beliefs were compared using non-parametric Wilcoxon Signed-Rank Tests in Jeffrey's Amazing Statistics Program (JASP), version 0.17.1.0, with a significance level set at alpha < .05. For each of the three suggestibility subscales tested (MISS, Kotov et al., 2004), item ratings were summed. The overall suggestibility score was calculated as the total of all subscales. Scores ranged between 12 and 60 for the Sensation Contagion (SC) scale, 13 – 65 for the

Physiological Reactivity (PHR) scale, 15 – 75 for the Psychosomatic Control (PSC) scale, and 40 – 200 for the overall suggestibility score. For each scale, participants' scores were averaged, and both the averages and standard deviations are reported. A higher score indicates a greater level of suggestibility.

3.2.2 Results

PSEs

In Experiment 1, only participants who demonstrated a positive association were included. If autosuggestion was effective in increasing the perception of the intensity of the stimulus at the reference finger, an increase in frequency perception for that finger would also be expected. Specifically, the greater the perceptual intensity experienced on the reference finger, should be accompanied by the higher the corresponding perceptual frequency. Conversely, the perceptual intensity at the comparison finger should be lower than that at the reference finger, leading to a lower perceived frequency. Therefore, in the *autosuggestion* condition, participants should more frequently report that the comparison stimuli had a lower frequency compared to the *baseline* condition. This would create a bias towards larger PSE values in the *autosuggestion* condition relative to the *baseline* condition, resulting in a rightward shift of the psychometric curve compared to the baseline. This expectation was confirmed, as the PSE in the *autosuggestion* condition (M = 5.52, SD = 2.40) was significantly higher compared to the *baseline* condition (M = 4.52, SD = 1.71), z = -2.415, p = .014, r = .39 (see **Figure 4a**).

Expectancy and suggestibility scores

Participants had a mean expectancy score of 55.18 (SD = 24.51) regarding their success in autosuggestion before beginning the task, where 0 represents minimal belief and 100 corresponds to a very strong belief. After completing the task, the mean self-efficacy rating was 47.15 (SD = 28.76) on the same scale. These two ratings did not differ significantly, z = 1.569, p = .123, r = .41.

In terms of suggestibility, participants scored M = 23.21 (SD = 6.43) on the Sensation Contagion scale, M = 46.32 (SD = 8.59) on the Physiological Reactivity scale, M = 38.74 (SD = 9.18) on the Psychosomatic Control scale, and M = 108.21 (SD = 17.28) as an overall score of suggestibility characteristics. These scores were classified as around average, based on norms acquired by Kotov et al., 2004). There were no outliers, as calculated by 3 SDs above the norms.

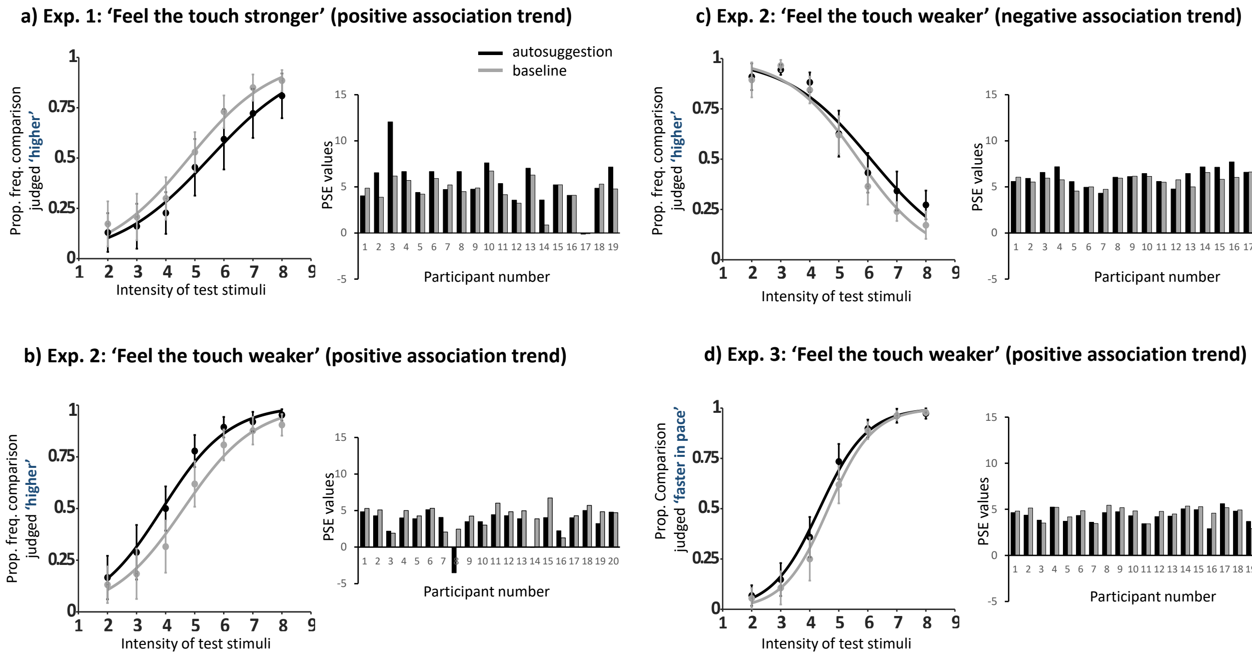

Figure 4. Overview of experimental results. The black color depicts autosuggestion results and the grey color— results in the baseline. The Y-axis of the psychometric graphs in Experiments 1 (**a**) and 2 (**b,c**) represent the proportion of responses where the comparison finger was judged as higher in frequency than the frequency at the reference finger. For Experiment 3 (**d**), the Y axis represents the proportion of responses where frequency at the comparison finger was judged as faster in pace than frequency at the reference finger. Note, that frequency on both fingers was always the same: 30 Hz. The X-axis of the psychometric graphs represents the levels of stimuli intensities applied to the comparison finger, from level 2 to level 8. Note that the intensity on the reference finger was always set to level 5. (**a**) In participants with a positive association trend after autosuggesting that the touch on the reference finger felt very strong, participants' frequency perception was significantly higher at the reference finger in the *autosuggestion* condition compared to the baseline. (**b**) This effect was reversed when a new sample was asked to autosuggest that the reference finger felt very weak. (**c**) In participants with a negative association trend after autosuggesting that the touch on the reference finger felt very weak, participants' frequency perception was significantly lower at the reference finger in the *autosuggestion* condition compared to the baseline. (**d**) A new sample of participants with the positive association trend was tested (Experiment 3), autosuggesting a weaker feeling of touch applied on the reference finger but judging the speed of pace perception. These results parallel the results obtained by participants with the positive association trend in Experiment 2 (**b**). Error bars represent 95% CIs. Bar graphs represent individual mean PSE values from participants obtained in the *autosuggestion* and *baseline* conditions. Visual inspection of (**b**) might suggest that participant number 8 is an outlier. This participant, however, passed through all exclusion criteria, and further analysis without this participant produces a similar pattern of results ($z = -2.173$, $p = .029$, $r = .50$). **Figure source:** Myga et al., *Sci. Rep.*, 2024, p. 3072

3.3 Experiment 2: autosuggestion weak

Experiment 2 aimed to test whether autosuggestion could effectively *reduce* the perceived intensity of touch. Consequently, in Experiment 2, participants were asked to use autosuggestion to "Feel the touch on the left finger as weak as possible". Following this, they were asked to judge whether the frequency of touch on the right finger was higher or lower than that on the left finger.

3.3.1 Materials and methods

Participants

Similar to Experiment 1, we focused on participants demonstrating a positive association. Our goal was to stop data collection once we obtained 20 datasets of individuals with a positive association trend and met the same inclusion criteria from Experiment 1. To reach this goal, we tested 54 participants. The datasets of 15 participants were removed from the analysis due to poor goodness-of-fit threshold ($R^2 \geq .40$). One participant withdrew consent, and their data was destroyed. Ultimately, the sample of interest consisted of 20 participants (9 females, M age = 26.80, SD = 3.04). Unexpectedly, we collected data from 18 participants who showed a negative association, significantly more than the two participants observed in Experiment 1. Given a large number of participants with a negative association tested in Experiment 2, these participants were included as a second independent group in the post hoc analyses (8 females, M age = 26.44, SD = 4.46). Most participants were right-handed except for one left-handed and one ambidextrous participant (M = 84.67, range: -89.47 – 100).

Procedure

The experimental procedure for Experiment 2 was the same as in Experiment 1, with one key difference: participants were instructed to change the perceived intensity of touch on their left finger to feel it as *weak* as possible. They were instructed to repeat thoughts like: "The touch on my left finger feels very weak". In this experiment, we administered an additional questionnaire: The Spontaneous Use of Imagery Scale (SUIS; Kosslyn et al., 1998), to assess the participants' tendency to spontaneously use imagery in their daily lives.

Analyses

The analyses conducted in Experiment 2 were the same as those from Experiment 1. Additionally, SUIS scores were summed to quantify participants' levels of spontaneous imagery use and then averaged across participants, with scores ranging from 12 to 60; higher scores reflect greater engagement with imagery. Furthermore, a two-sample non-parametric Mann–Whitney U-test was performed using JASP version 0.17.1.0 to compare mean expectancy and self-efficacy scores between the group with a positive association and the group with a negative association. Effect sizes were calculated using the rank biserial correlation.

3.3.2 Results

PSEs

Two groups were analyzed: the positive association group and the negative association group. If autosuggestion effectively induced the perception of weaker intensity in the left (autosuggested) finger for the positive association group, then frequency perception should decrease for that finger. Consequently, in the *autosuggestion* condition, participants should more frequently report that the comparison stimuli had a higher frequency compared to the *baseline* condition. This would result in a bias toward smaller PSE values in the *autosuggestion* condition relative to the *baseline* condition, causing the psychometric curve to shift to the left of the baseline curve.

In the negative association group, the perception of a weaker stimulus on the left (autosuggested) finger should lead to an increase in frequency perception for that finger. As a result, in the *autosuggestion* condition, participants would be expected to more frequently report that the comparison stimuli had a lower frequency compared to the baseline. This would create a bias toward smaller PSE values in the *autosuggestion* condition relative to the *baseline* condition. Additionally, given the negative association, the psychometric curve should also shift to the left of the baseline curve.

Figure 4 shows the results for participants with a positive association (**4b**) and those with a negative association (**4c**). For participants with a positive association, as expected, the PSE values in the autosuggestion *condition* (M = 3.40, SD = 2.02) were significantly lower as compared to the *baseline* condition (M = 4.30, SD = 1.46), z = -2.389, p = .015, r = .38. This suggests that during autosuggestion, the frequency perception on the autosuggested finger was lower compared to baseline, which is reflected by participants responding more often that the comparison finger had a higher frequency. Visual inspection of **Figure 4b** might suggest that Participant Number 8 is an outlier. However, this participant met all exclusion criteria, and further analysis without this participant yielded a similar pattern of results, z = -2.173, p = .029, r = .50.

Counterintuitively, participants with a negative association exhibited a significantly higher mean PSE in the *autosuggestion* condition (M = 6.21, SD = .96) compared to the *baseline* condition (M = 5.72, SD = .58), z = -2.199, p = .027, r = .37. This indicates that these participants more frequently reported the comparison finger having a higher frequency than the autosuggested finger. Note that the opposite trend would be present if autosuggestion reduced the perceived intensity.

Expectancy and suggestibility scores

In participants with a negative association, the mean expectancy score for succeeding in autosuggestion before starting the task was M = 39.45 (SD = 28.43), and for participants with a positive association: M = 52.00 (SD = 24.65). The mean self-efficacy ratings after finishing the task were M = 39.93 (SD = 27.96) and M = 49.54 (SD = 28.29), respectively. These ratings did not differ significantly before and after the experiment, positive association: z = -.149, p = .898, r = .01; negative association: z = -.479, p =.648, r = .02. In addition, there was no significant difference between mean expectancy ratings, U = 230.00, p = .149, r = .278 or mean self-efficacy ratings, U = 217.50, p = .279, r = .208 between participants with positive and negative associations.

On average, participants scored: M = 22.40 (SD = 5.45) and M = 22.39 (SD = 6.84) on Sensation Contagion scale, M = 46,70 (SD = 10.78) and M = 46.44 (SD = 6.55) on Physiological Reactivity scale, M = 39.55 (SD = 9.58) and M = 38.56 (SD = 11.31) on Psychosomatic Control scale, and M = 108.65 (SD = 22.47) and M = 107.39 (SD = 20.05) as an overall score of suggestibility characteristics, for positive and negative trends respectively. Participants were thus average-suggestible based on norms acquired by Kotov et al., 2004. Participants' mean score on the Spontaneous Use of Imagery scale was M = 41.45 (SD = 7.69) and M = 38.33 (SD = 7.33) for positive and negative trends, respectively, indicating the average use of spontaneous imagery in daily life (based on norms gathered on a sample size of N = 491 by Nelis et al., 2014). In both groups, there were no outliers, as measured by 3 SDs above the norms.

3.4 Experiment 3: autosuggestion weak – modified mode of responses

In Experiment 3, our goal was to ensure that the results obtained in the previous two experiments reflected genuine changes in perception and not a general response bias. In the earlier experiments, participants were asked to feel the touches "stronger" or "weaker"; which may have unintentionally interfered with their ability to accurately assess whether the frequency felt "higher" or "lower". This concern arises because terms like "high" and "low" are commonly associated with both intensity and frequency in everyday language, creating a potential semantic overlap. For example, a Google search returns approximately 88 million results linking "high" to "intensity" and 36 million results linking "low" to "intensity," illustrating this strong conceptual connection in everyday language. Given this potential confound, it is possible that after associating the reference finger's touch as "weaker" (i.e., lower in intensity), participants might have been biased toward reporting the comparison finger as "higher" in frequency.

To address this, in Experiment 3, we used words that do not easily associate with "stronger" or "weaker" – specifically, "faster" and "slower". It's worth noting that the terms "fast intensity" and "slow intensity" yield relatively fewer Google entries, with only 44,000 and 17,000 entries, respectively. This suggests that frequently associating the reference finger's touch as "weaker" in intensity is unlikely to result in participants reporting more frequently the comparison finger to have a "faster pace".

Participants were instructed to focus on the "pace" of the stimuli, defined as how quickly or slowly the taps occurred during each 500 ms vibration. This was demonstrated by the experimenter, who applied "fast" and "slow" taps on the participant's hand to clarify the concept. Additionally, like in Experiment 2, participants were instructed to use autosuggestion to *reduce* the perceived intensity of the touch.

3.4.1 Materials and methods

Participants

As in Experiment 2, we aimed to stop sample collection once 20 datasets with a positive association trend were obtained. The inclusion and exclusion criteria for Experiment 3 remained consistent with those applied in Experiments 1 and 2. To achieve this target, 24 participants were initially tested. Three datasets were excluded due to poor goodness-of-fit ($R^2 \geq .40$). One participant showed a negative association trend and their data was excluded. We analyzed data from 20 participants (5 females, M age 24.80, SD = 2.04), 16 participants were right-handed, 2 were left-handed, and 2 were ambidextrous (M = 67.15, range: − 100 – 100).

Procedure

The experimental procedure for Experiment 3 was the same as in Experiment 2, with one key difference: instead of indicating whether the touch on the comparison finger was *higher* or *lower in frequency* than the touch on the autosuggested finger, participants now responded whether the touch on the comparison finger was *faster* or *slower in pace*.

Unlike previous experiments, participants did not receive the information sheet before the session; it was provided on the day of testing. Given the extended duration of the experiment (approximately 2.5-3 hours), participants completed the Short Suggestibility Scale (SSS), a subscale of the Multidimensional Iowa Suggestibility Scale (Kotov et al., 2004), which ranges from 21 to 105, with higher scores indicating greater suggestibility. In addition, participants provided a qualitative description of their strategy for performing autosuggestion during the task.

3.4.2 Results

PSEs

Note that in Experiment 3, only participants with a positive association were included in the analysis, as only one participant showed a negative trend (see **Figure 4d**). The results showed that the psychometric curve during the autosuggestion *condition* (M PSE = 4.34, SD = .67), was shifted towards the left as compared to the *baseline* condition (M PSE = 4.62, SD = .74), z = -2.240, p = .024, r = .35. This indicates that, even with the revised instructions that avoid the association of responses, the results of Experiment 3 replicate those of Experiment 2. In both Experiments, 2 and 3, participants with a positive association responded more often that the frequency on the comparison finger was faster (or higher, in Experiment 2) while autosuggesting that the reference finger felt very weak, compared to the *baseline* condition.

Expectancy, suggestibility, and imagery scores

Participants' mean expectation score for success in autosuggestion before starting the task was 47.22 (SD = 29.25). After completing the task, their mean self-efficacy rating increased to 58.24 (SD = 29.79). These beliefs did not differ significantly, z = -1.867, p = .064, r = .09.

On average, participants scored M = 50.85 (SD = 13.98) on the Short Suggestibility Scale, and M = 43.25 (SD = 7.45) on the Spontaneous Use of Imagery scale. All participants were average suggestible (based on norms reported by Kotov et al., 2004) and higher than average imagers (based on norms gathered on a sample size of N = 491 by Nelis et al., 2014). There were no outliers as measured by 3 SDs above the norms.

Task strategies overview from follow-up questionnaires

Of the 20 participants, 14 reported predominantly creating and reiterating thoughts that the touch on the autosuggested finger felt weaker. Among these, 2 participants also employed imagery. Five participants did not provide detailed descriptions of their strategies, while 1 participant reported attempting to directly influence frequency perception through autosuggestion. Specifically, this participant noted that the touch on the left (autosuggested) finger "should vibrate less, while the right-hand index finger should vibrate more". It is important to note that the overall effect of autosuggestion observed in this experiment was not driven by this participant, as their PSEs in the *autosuggestion* and *baseline* conditions were nearly identical (PSE autosuggestion = 5.25; PSE baseline = 5.21). For detailed descriptions of participants' use of autosuggestion, please refer to the following link: https:// osf. io/ 7hd5a/? view_only= 321a7 ad916 e64f5 3a115 96ecc d55bd 7e.

3.5 Discussion

The results of Chapter 1 indicate that the inner reiteration of a thought alters participants' tactile perception using a response orthogonal to the suggested variable. Specifically, participants internally repeated thoughts that tactile touch intensities on the reference finger felt very strong or very weak (compared to what they actually were) while they judged tactile frequency perception. Given that participants were naïve about the relationship between tactile intensity and frequency, this design minimized demand characteristics to influence the results. Moreover, even if participants were making intuitive guesses about the best-suited responses, they could not predict the direction of the effect, because the relationship between tactile amplitude and frequency perception varies across individuals.

The results showed that after autosuggestion that the touch on the reference finger feels very strong, perceptual judgments of frequency on that finger were higher than in the *baseline* condition (Experiment 1). Conversely, when participants repeated the thought that touches on their reference finger felt weaker, perceptual judgments of frequency on that finger were lower than in the *baseline* condition (Experiment 2). This was evident in participants with a positive association (i.e., perceiving higher frequencies at higher intensities) in both experiments, indicating that the inner reiteration of thought can indeed shift tactile perception into the expected (autosuggested) outcome.

For those participants who had a negative association (i.e., perceiving lower frequencies at higher intensities), autosuggestion yielded counterintuitive results. When these participants repeated the thought that the touches felt weaker (Experiment 2), it led to a decrease in frequency perception, rather than an increase. Specifically, when participants with a negative association (but not those with a positive association) attempted to reduce the perceived intensity of the touch, they reported a frequency change typically associated with a stronger tactile perception.

These findings are unlikely the result from differing expectations about the success of autosuggestion, since both groups had similar mean expectation scores. One possible explanation is a response bias. More specifically, after internally repeating the sentence “The touch to my left finger feels very weak”, participants might have become more inclined to respond “Touch to the right finger feels high in frequency” given both verbal constructions are closely connected. To address this possibility, in Experiment 3 we asked participants to judge whether the touches on the comparison finger felt faster or slower than those on the reference finger. This should create a clearer distinction between intensity (strong vs. weak) and frequency (fast vs. slow). Results from Experiment 3 replicated the earlier findings in the positive association group, suggesting that the observed effects were not due to response bias or confusion between the intensity and frequency.

Previous studies suggest that the perception of magnitudes can be mutually influenced through a “generalized magnitude system”, with the idea that different features such as size, time, or number are processed by a common mechanism (e.g. Lourenco & Longo, 2011; Riemer et al., 2022; Xuan et al., 2007). For example, larger objects are perceived as lasting longer, being brighter, or containing more elements (Xuan et al., 2007). However, the finding that frequency and intensity were inversely related for some participants suggests that this coupling may not operate under the same generic magnitude representation during information processing. Nevertheless, it remains possible that the effect of autosuggestion in this task reflects a shift within this generalized magnitude system. The idea is that when participants are required to determine which of two stimuli is greater in magnitude, in this case, frequency, their judgments may be influenced by the magnitude of the stimuli on another dimension, in this case, intensity. Therefore, a perceived decrease in intensity may bias participants to perceive a lower frequency, even if the actual coupling between these two features is inconsistent. In other words, the results obtained here may reflect number processing, where “less” in one dimension (i.e., intensity) is associated with “less” in another dimension (i.e., frequency; Lourenco & Longo, 2011). This interpretation aligns with the findings from participants with both positive and negative intensity-frequency associations.

Autosuggestion is unique because it allows individuals to actively generate perceptual changes of their own choices. However, the notion that somatosensory perception can be modified via top-down modulation is not novel. For instance, visually atteding toward one’s own body enhances the detection and discrimination of cutaneous stimuli (Cardini et al., 2011; Gomez-Ramirez et al., 2016), elicits spontaneous sensations in the skin (Michael & Naveteur, 2011), increases pain thresholds (Longo et al., 2009), and can even modulate the temperature of the attended skin (Sadibolova & Longo, 2014). Conversely, directing attention away from the body reduces tactile stimulus perception (Eimer et al., 2004). In these paradigms, however, participants are typically not asked to equally attend but produce or modify opposite sensations (either increase or decrease the sensation, as we did here.

In our experiments, participants were instructed to focus their attention on perceiving the intensity of non-noxious stimulus. Indeed, it may be more relevant and ecologically valid to investigate the perception of painful stimuli, rather than modifying emotionally neutral stimuli in a healthy population. Research on discriminative touch, such as the present study, offers foundational insights into the processes involved in somatosensory perception. The findings indicate that the perception of tactile intensity is not solely a product of bottom-up processing, but it can also be intentionally modified by top-down processes. This raises the question of whether the results from discriminative touch can be extrapolated to pain sensations. While discriminative touch provides detailed tactile information, pain serves as a protective mechanism, warning the body of potential harm. Given that both forms of somatosensory information are processed by different, albeit overlapping, neural systems (Prescott &

Ratté, 2017), it cannot be assumed that the effects of autosuggestion on discriminative touch will parallel those observed in pain.

It is important to note that stimulation was applied to spatially separate body parts (i.e., index fingers of both hands), unlike the approach taken by Morley and Rowe (Morley & Rowe, 1990), who presented sequential stimuli on the same fingertip. This experimental design facilitates cognitive differentiation between autosuggestion, consistently applied to the left index finger, and the comparison consistently applied to the right index finger. We anticipated that participants would find it less demanding to shift their attention away from the task of autosuggestion when the two touches were separated in space, compared to when the touches were applied to the same fingertip. It is equally true, however, that attention switching between two stimuli can become easier with decreasing external distance between them (Lakatos & Shepard, 1997). Nevertheless, if the effects observed in autosuggestion were solely mediated by differences in attention distribution between each finger, we would not expect to see differential effects between the *weak* and *strong* conditions. In both conditions, participants were instructed to focus on their left finger while enhancing or reducing their tactile sensations and then shift their attention to their right finger to provide accurate difference ratings. They were explicitly informed that attending on only one finger would impair their ability to give accurate ratings.

While instructing participants to adhere to task demands is essential, it does not guarantee compliance. Therefore, we cannot determine if all participants directed their attention, in sequence, to both fingers. However, if participants had indeed attended more to the autosuggested finger than the comparison finger during the "stronger" instruction and less during the "weaker" instruction, we would expect to see flatter psychometric curves in the latter condition, rather than the observed changes in PSEs. Yet this was not the case.

Roy and Hollins (1998) proposed that the ratio of recruitment between Pacinian corpuscles (PA) and rapidly adapting (RA) sensory fibers might be the origin of the frequency-intensity associations discussed in this study. The hypothesis is based on the observation that at specific vibration frequencies, the recruitment ratio of PC and RA fibers varies in response to changes in vibration intensity. For instance, at lower amplitudes, the activation predominantly involves PC fibers, whereas at higher amplitudes, a greater proportion of the recruited fibers would likely be of the RA class (Talbot et al., 1968 for evidence in monkey). Assuming that RA and PC sensory fibers have different sensitivities to vibration, differences in recruitment rates could consequently manifest as variations in frequency perception. However, the pattern of frequency-amplitude was well-described by a ratio model in only three out of the four participants examined by Roy and Hollins (1998), and indeed, in those showing a negative trend. Similar mixed indicators regarding the plausibility of the ratio model were reported in a prior study by Morley and Rowe (1990). An alternative hypothesis suggested for frequency-intensity associations (Morley & Rowe, 1990; von Békésy, 1959) involves a temporal patterning of impulse activity (temporal pattern coding), where neural responses are phase-locked to the vibration of the tactile stimulus (Rowe, 1990). In this view, high vibration intensities may inhibit neural firing during certain cycles, leading to a perception of lower frequency. Yet again, this explanation would only account for the negative association and not the positive one. Furthermore, it has been demonstrated that cortical neurons are unlikely to skip a cycle as vibration amplitude increases (Mountcastle et al., 1969).

To the best of our current knowledge, no alternative hypotheses have been put forward to explain the frequency-intensity interaction discussed here. It is, however, not surprising that the origins of this interaction remain unclear, as the exact way in which stimulus frequency and amplitude are translated into perception of pitch and intensity, when considered in isolation, are not clear either (Bensmaia, 2008; Birznieks & Vickery, 2017; Muniak et al., 2007). Moreover, the neural mechanisms underlying the association between frequency and intensity in touch may differ from those that govern the perception of pitch and intensity, indicating a potential role for higher-level cognitive factors, such as the generalized magnitude system mentioned earlier. Once the neural and peripheral mechanisms that underlie tactile frequency-intensity coupling are clarified, it will be possible to formulate hypotheses regarding why cognitive manipulations differentially affect individuals with positive versus negative associations, as shown in this study.

The specific brain mechanisms involved in autosuggestion remain an open question and carefully designed neuroimaging studies could enhance our understanding of the neural processes at play. Lena et al. (2022) concisely summarized the literature regarding the impact of semantic aspects of language and verbal suggestions on pain perception. Their findings indicate that the use of pain-related vocabulary is linked to alterations in pain perception at both behavioral and neural levels. Several mechanisms have been proposed to explain these effects, including semantic-related priming (Vukovic et al., 2018). Given that participants in our study were instructed to reiterate words describing the desired intensity of tactile sensations, one might anticipate that a similar brain network is involved in the effect of autosuggestion when delivered in verbal form. However, further research is necessary to explore this possibility and to compare the neural networks engaged in autosuggestion with those activated during mental imagery. Such studies will be fundamental for understanding which brain mechanisms underlie autosuggestion.

Limitations of the study

Despite employing a novel approach to studying the effects of autosuggestion, the current study has several limitations. The primary drawback is the inability to disentangle the effects of autosuggestion from potential confounding influences of other top-down mental processes, such as visual imagery and attention. Here, visual imagery refers to the use of images, such as a protective glove, to evoke sensations of reduced intensity. Although participants were instructed to focus solely on the effects of inner thought repetition, the possibility of interference from other cognitive processes cannot be excluded.

Also, attention might have influenced our results. In Experiment 1, participants were asked to direct attention to the autosuggested finger and to try to feel the touches at a stronger intensity. It can therefore not be determined if attentional enhancement or the will to perceive the touches strongly led to the desired effects. However, in Experiment 2 and Experiment 3, participants directed their attention to the autosuggested finger while being asked to feel the touches at a weaker intensity. Given the direction of the effect was modulated in our studies, attentional enhancement cannot explain these results. However, it is possible that to successfully solve the task in Experiment 2 and Experiment 3, participants directed their attention away from their finger, to, for example, other parts of their body, or to the surroundings. This could also have resulted in a success in lowering the perceived intensity of touches. Therefore, we cannot exclude that attention influences the results of the present study. However, diminished attention to the autosuggested finger should have impacted the comparative ratings between the two fingers, potentially resulting in flatter psychometric curves in the *weaker* condition, which was not the case.

Another potential confound is the small sample size. To reduce the impact of this limitation, data were analyzed using the non-parametric Wilcoxon Singed-Ranks test, allowing for the extraction of exact p-values based on the actual distributions of the data. More importantly, though, the results of experiments 1 and 2 were replicated with an independent cohort of participants. However, given the small sample sizes, the number of participants was too low to perform reliable correlations between PSE values and self-reported scores, such as expectancies, suggestibility, and self-efficacy reports (see: Schönbrodt & Perugini, 2013). Therefore, further research with a larger sample size is essential to confirm the present findings and draw more robust conclusions, particularly in light of the significant variability observed in the coupling between frequency and intensity. This variability refers not only to the previously described Békésy and reversed-Békésy effects but also to the strength of these effects. Part of this variability might be grounded in the difficulty in separating the perceptual amplitude and frequency components of the vibrotactile stimuli. Although participants received training to discriminate between these two features, and we are confident they were able to do so, the task remains challenging. Differences in the ability to distinguish intensity from frequency could result in an increase in participants for whom data could not be accurately fitted.

Concluding remarks

The current study introduces a novel method for investigating the impact of autosuggestion on discriminative touch while minimizing the influence of response biases and demand characteristics. The findings indicate that the inner reiteration of a thought significantly changes participants' tactile perception. However, the underlying mechanisms behind these changes remain unclear. Notably, the observation of opposite effects between the positive and negative association groups suggests that the effects of autosuggestion in this context may reflect modifications in a generalized magnitude system. Given its well-acknowledged limitations, the present research provides the first empirical framework supporting the potential benefits of using autosuggestion in both everyday life and clinical settings. Nevertheless, it underscores the need for more studies to systematically address response biases when investigating the effects of self-directed suggestion. Moreover, the experimental design can be expanded in future research to explore other forms of suggestion, such as placebo effects or heterosuggestion. In the next chapter, I will introduce two experiments directly comparing the effects of autosuggestion with placebo using a modified experimental paradigm.

Data availability

All data, analysis scripts, have been made publicly available via OSF and can be accessed at https:// osf. io/ 7hd5a/?view_ only= 321a7 ad916 e64f5 3a115 96ecc d55bd 7e.

Chapter 4

Study 2: Contrasting the effects of autosuggestion versus tDCS placebo on tactile perception

4.1 Introduction

The placebo effect is a widely recognized phenomenon in medical and psychological research, characterized by patients reporting symptom improvements even when receiving an inactive treatment (Shapiro & Shapiro, 2000). Both autosuggestion and placebo involve suggestions aimed at influencing perceptual states. While the effects of externally administered placebos (heterosuggestion) are well-documented in the literature (Benedetti & Amanzio, 2011; Colloca et al., 2023; Colloca & Benedetti, 2005; Horing et al., 2014; Miller & Kaptchuk, 2008; Schwarz & Büchel, 2015; Tracey, 2010), the effects of self-directed suggestion (i.e., autosuggestion) remain underexplored and lack scientific validation.

Addressing the gap in the existing literature on autosuggestion is of high interest, as it presents distinct advantages over heterosuggestion. One significant benefit of autosuggestion is its independence from external influence, allowing individuals to focus on their concerns and desired outcomes without fear of judgment. Additionally, since autosuggestion does not require the involvement of another person, it can be practiced anytime and anywhere, enhancing accessibility and reducing potential costs associated with treatment. It is important to emphasize that highlighting the benefits of autosuggestion is not meant to diminish the value of placebos or other types of heterosuggestion; rather, it aims to introduce a complementary approach that can be employed when placebos are unavailable or to enhance their efficacy.

The primary objective of the study outlined in this chapter was to evaluate and compare the efficacy of the placebo effect, a widely recognized phenomenon in medical practice (Koshi & Short, 2007), with that of autosuggestion. As a placebo, we used a custom-made device resembling transcranial direct current stimulation (tDCS; see **Figure 5**). The detailed implementation of the placebo is described below. In both experiments (autosuggestion and placebo) we used a similar implicit paradigm as in Study 1 (Chapter 3).

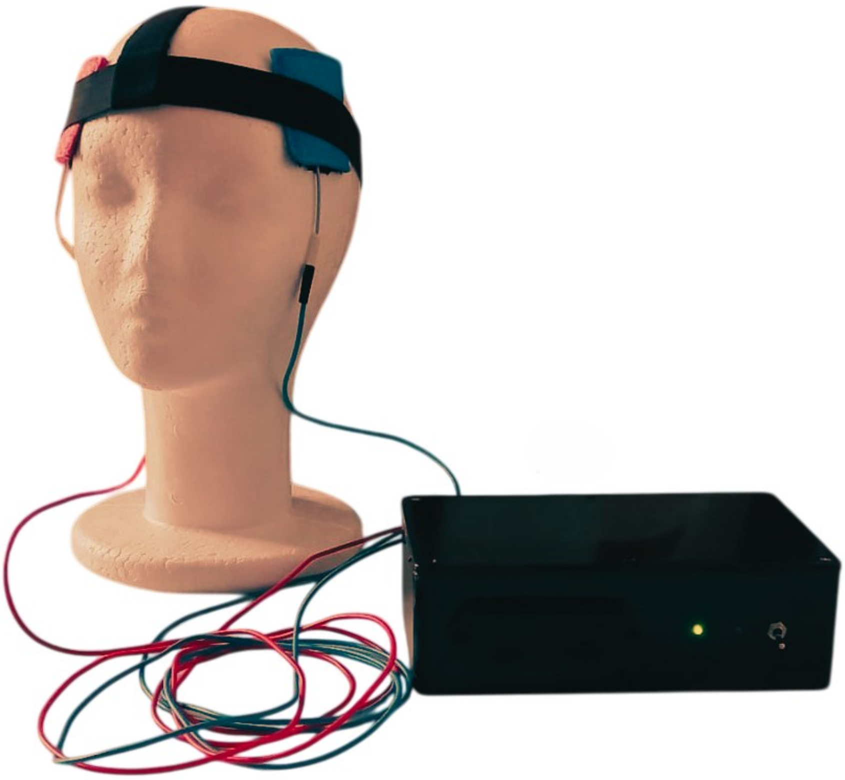

Figure 5. In-house placebo tDCS-like device. The in-house transcranial direct current stimulation (tDCS)-like device was used as placebo manipulation. The device was made up of a black box with a switch that lit up green when turned on. The following components of the device corresponded to the actual tDCS system: two electrodes attached to the back of the box by red and blue cables, mimicking an anode and a cathode, respectively. These electrodes were covered in pockets made of cellulose cloth and positioned on the head under an elastic head strap. Please note that the positioning of the pouches with electrodes in the illustration is purely demonstrative.

To optimize the effects of autosuggestion and placebo, we modified the original experimental paradigm outlined in Chapter 3. A within-subjects design was employed to increase statistical power and facilitate comparisons between the *weak* and *strong* conditions. In Experiment 1 (placebo tDCS) participants were misled into believing that the tDCS current would either enhance (the *strong* condition) or diminish (the *weak* condition) the perceived intensity of touch on the reference finger during two separate conditions. In Experiment 2 (autosuggestion), participants were asked to create these perceptual changes by themselves, according to the same guidelines as those presented in detail in Study 1.

Furthermore, conditioning trials were randomly interspersed with regular trials to reinforce the placebo effects. In our paradigm, regular trials mirror the trial structure from the previous chapter, where the stimulus intensity on the autosuggested, reference finger remained constant. In contrast, conditioning trials vary the intensity of touches delivered to the reference finger, either higher or lower than standard intensity, for *strong* or *weak* conditions, respectively.

Typically, researchers pair an inactive placebo, often in cream form, with covert variations in stimulus intensity to induce analgesic or enhanced perception effects (e.g., Fiorio et al., 2012; Voudouris et al., 1985; Wai-Lan Yeung et al., 2020). For example, Fiorio and colleagues (2012) explored the impact of a placebo cream on tactile intensity perception. Both experimental and control groups received identical non-noxious electric shocks to assess tactile sensations before and after applying the cream. The experiment comprised three blocks of trials. In the first and third blocks, tactile stimulation remained consistent with non-noxious intensity. However, in the second block, stimulation intensity was heightened. The control group was informed about this change and about the cream's ineffectiveness. In contrast, the experimental group was conditioned to believe that the cream would enhance tactile perception. Results indicated that the experimental group reported stronger tactile sensations post-treatment and showed enhanced somatosensory cortical responses.

Due to time constraints, rather than incorporating an additional experimental block to our paradigm, we adapted the conditioning procedure. Specifically, we integrated conditioning trials by dividing each original experimental block, which solely included regular trials, into 7 mini-blocks. Each of these mini-blocks began with two pairs of conditioning trials. In these conditioning trials, touches applied to the autosuggested, reference finger varied in intensity – higher or lower – depending on whether the condition was *strong* or *weak*. We aimed to induce these perceptions into subsequent regular trials, where the stimulus intensity remained constant (please refer to detailed experimental parameters below), thereby potentially amplifying the observed effects of one or both manipulations.

Finally, to address attentional influences, we introduced catch trials where the frequency of stimulation on the comparison finger differed from that on the reference finger. This allowed us to calculate the percentage of correct responses for these trials. Notably, in the original paradigm, this assessment was not feasible because the frequency on both fingers was always identical. This approach enabled us to evaluate participants' attentional engagement in the tactile task across the two experimental conditions (*strong* and *weak*).

Although participants were instructed to attend equally to touches in both conditions, they may have reduced their attentional focus during the *weak* condition. Our hypothesis was that strategies such as increased attention to tactile stimuli in the *strong* condition or diverting attention away from tactile stimulation to reduce tactile intensity perception would lead to fewer correct responses and flatter slopes in the psychometric function for the *weak* condition compared to the *strong* condition. This aligns with findings in the literature (see Chapters 1 and 2 for more details), which suggest that directing attention to the body enhances tactile sensations (e.g., Cardini et al., 2011; Longo et al., 2009; Sadibolova & Longo, 2014; Gomez-Ramirez et al., 2016) and may even evoke tactile sensations (Michael & Naveteur, 2011). Conversely, directing attention away from the body reduces perception of tactile stimuli (Eimer et al., 2004).

To directly compare the effects of the tDCS placebo using the enhanced paradigm with those of autosuggestion, the same group of participants were invited a second time for re-testing two to three weeks later. This time, they were instructed to modify their perception of tactile intensity through autosuggestion, mirroring the approach used in the experiments detailed in Chapter 3, but using the same enhanced paradigm. We anticipated that if participants exhibited greater motivation to actively initiate changes in tactile perception, autosuggestion would yield more pronounced effects than the placebo. Conversely, if the authority of the experimenter and the suggestions provided had a more substantial influence, autosuggestion might demonstrate weaker effects compared to the placebo.

4.2 Experiment 1: placebo tDCS

Similar to Experiment 3 in Chapter 3, participants were asked to determine whether the touches on the comparison finger were delivered at a faster or slower pace than those on the reference finger. Here however, participants were misled into believing that the tDCS current would either enhance (the *strong* condition) or diminish (the *weak* condition) the perceived intensity of touch on the reference finger.

4.2.1 Materials and methods

Participants

In alignment with Experiment 1 from the previous chapter, our goal was to test 20 participants with a positive association trend. In this study, 35 participants were screened during the baseline task, of which 21 demonstrated a positive association trend and were invited to complete the full experiment. One participant withdrew midway through the testing and their data were excluded. As a result, the final sample included 20 participants, all of whom met the goodness-of-fit threshold ($R^2 \geq .40$) in the regular trials for both conditions (8 females, M age = 25.6, SD = 2.68). All participants were right-handed, (M = 94.19, range: 64.7 – 100). Those participants who showed a negative trend were tested in another experiment, not reported in this thesis. All methods were performed following the guidelines and regulations set out by the ethics committee (ethics code 01/19) of the Otto-von-Guericke University Magdeburg and in compliance with guidelines defined by the Leibniz Institute for Neurobiology (LIN) in Magdeburg, where testing took place.

Stimuli

The stimuli in the frequency-intensity discrimination training and baseline were the same square wave stimuli as those delivered in experiments in Study 1. In the main experimental session, stimuli were sine wave taps, lasting 500 ms, and administered individually to each fingertip, creating a vibrating sensation. It is important to note that the use of square and sine wave stimuli arose from the transition from Solenoid Tappers (MSTC3- 10M, M & E Solve) to the Dancer Design device in this and future studies. This switch required additional time due to coding issues and various organizational challenges, which is why both devices were employed in this study. Stimulus delivery was controlled using MATLAB script, version R2015a (MathWorks), and Psychtoolbox, version 3.0.11 (Brainard, 1997; Kleiner et al., 2007).

To implement the placebo manipulation, we built an inactive tDCS-like device. The device was made of a black box with a switch that lit up green when turned on. Two electrodes were connected to the back of the box using red and blue wires, resembling an anode and cathode setup. These electrodes were wrapped in cellulose cloth pouches and placed on the participant's head, secured by an elastic headband (see **Figure 5**), and these elements corresponded to the actual tDCS system (e.g., Clinical Brain, n.d.). Additionally, a sham skin conductance device was attached to the participants' reference finger during the main experimental part as part of the placebo elements.

Procedure

Participants were seated in front of a 24.4-inch monitor, positioned approximately 56 cm away from their eyes for optimal viewing. Before the experiment, participants received an information sheet outlining the study and the therapeutic applications of tDCS, to enhance the suggestive effects of the procedure. Next, the experimenter provided participants with a detailed explanation regarding the study's objectives and the mechanism of tDCS. In essence, participants were informed that tDCS has demonstrated effectiveness across various contexts. For instance, in healthy populations, tDCS has been shown to enhance cognition (Dedoncker et al., 2016). Moreover, in the somatosensory domain, studies indicate that tDCS effectively modulates tactile perception (Boggio et al., 2008; Fujimoto et al., 2016; Rogalewski et al., 2004). Participants were informed that the study aimed to investigate whether tDCS could alter tactile perception. Positive findings could potentially pave the way for future research involving clinical populations, aiming to develop treatments that enhance functional recovery in individuals with impaired tactile perception.

The experiment consisted of three parts, which were explained to participants before it started, as follows:

Frequency-intensity discrimination training and Baseline

These sessions were identical to the equivalent sessions in experiments on autosuggestion in Chapter 3. To briefly summarize, the practice session consisted of two blocks with eight trials each. Stimulus intensity increased gradually across trials, while frequencies for paired stimuli were randomly selected from combinations such as 10 – 30 Hz, 30 – 10 Hz, 20 – 40 Hz, and 40 – 20 Hz (the first value corresponded to the frequency delivered to the reference finger, and the second value – to the frequency on the comparison finger). Participants reported whether the frequency of touches on the comparison finger (right index) felt higher or lower compared to those on the reference finger (left index). After each response feedback was provided: “correct” or “wrong”. Responses in this and the following experimental parts were given via foot presses, consistently with the procedures used in previous experiments.

Main experimental session (testing the effects of strong vs weak placebo tDCS stimulation)

Before starting this session, participants were reminded how tDCS works. Specifically, the experimenter explained that tDCS induced changes in neuronal excitability and activity within the targeted brain area through deliberate electrode positioning on the scalp, with the positive anode represented in red and the negative cathode in blue (see **Figure 5**). In the *strong* condition, the red electrode was placed on the opposite side of the head from the stimulated finger, over the corresponding area of the somatosensory cortex at C4, according to the 10-20 EEG system. The blue electrode was positioned on the same side of the head as the stimulated finger, serving as the sham “reference electrode”. Conversely, in the *weak* condition, the electrode placement was reversed. The experimenter drew participants’ attention to the colors of the electrodes to further enhance the placebo effects, as research suggests that color can significantly influence expectations and the elicitation of placebo effects, particularly in studies comparing the administration of pills in various colors and shapes (Wan et al., 2015). Participants were also reassured that tDCS brain stimulation posed no risk. Following this, participants’ head circumference was measured. While this step was redundant since the elastic band used was adjustable for all head sizes, it was included to create a sense of seriousness to the procedure. Finally, tactile stimulators were attached to the participants’ index fingers.

Participants were informed that they would receive two touches: one on the left index finger (the reference finger) followed by one on the right index finger (the comparison finger). Their task was two-fold: first, to pay attention to any changes in the intensity or weakening of the tactile sensation on the left finger that were supposed to occur, and second, to indicate whether the pace of the touch on the right index finger felt faster or slower compared to the left. They were informed that the device would modulate their perception of the touch on the left index finger, resulting in either a very strong sensation (the *strong* condition) or a very weak one (the *weak* condition). The two conditions: *strong* and *weak*, consisted of two blocks, presented in ABBA order, with the first condition counterbalanced across participants. Each block was further divided into 7 mini-blocks. There were 18 trials in each mini-block (126 trials per block; 504 trials in the whole experiment). Participants were allowed one untimed break in the middle of each block.

At the beginning of each block, participants experienced a demonstration in which they received five sample touches on their reference finger, with the placebo equipment turned off. These touches were intended to illustrate the perceived intensity of stimulation they might experience when the device was later activated, set at intensity levels of 0.8 for the *strong* condition and 0.4 for the *weak* condition. This demonstration aimed to establish expectations that touches on the reference finger would indeed feel stronger or weaker based on the experimental condition. Following this, the experimenter activated the sham device by flipping the switch on the black box, causing a green light to illuminate and a loud sound to play, misleading participants into believing the tDCS was on and working. These auditory and visual cues were specifically designed to enhance participants' conviction in the authenticity of the equipment being used. Following this, participants underwent a one-minute waiting period during which the device supposedly calibrated the signal. While this process was presented as an adjustment designed to induce changes in tactile intensity perception, it was, in fact, a period of inactivity with no actual calibration taking place.

To reinforce the belief that the device stimulated participants' brains, each mini-block began with two conditioning trials (see detailed description in the Introduction of this chapter), comprising a total of 14 trials within each block, followed by the 16 standard intensity trials. In the strong and weak conditions, the intensity in the conditioning trials on the reference finger was set at 0.8 and 0.4, respectively. Throughout the experiment, the reference finger maintained a constant intensity of 0.6 at a frequency of 30 Hz. In contrast, the stimuli on the comparison finger varied in intensity from 0.3 to 0.9 in increments of 0.1 units, resulting in seven distinct intensity levels, while the frequency remained stable at 30 Hz. At the end of each mini-block, participants were asked to evaluate the perceived reduction or amplification of touch intensity experienced during the preceding trials. They responded using the same analog scale employed in previous experiments (Chapter 3), where a score of 0 indicated no perceptible change and a score of 100 represented a strongly felt change in intensity perception. These questions were intended to direct participants' attention towards any potential perceptual changes and encourage them to detect such alterations.

To evaluate participants' engagement in the task, we integrated catch trials into the experimental design, consisting of 14 catch trials per block. These trials introduced variations in the frequency of tactile stimuli delivered to the fingers. Specifically, in 7 trials per block, the frequency on the comparison finger was set higher than that on the reference finger (40 Hz), while in the remaining 7 trials, the frequency on the comparison finger was lower (20 Hz). These catch trials were randomized within each block. Throughout the experiment, participants listened to white noise to mask any auditory noise generated by the tappers.

At the end of the experiment, participants were asked the final questions: 1) To what extent, on average, did they perceive touch intensity to be amplified in the *amplification* condition? 2) To what extent, on average, was touch intensity perceived to be reduced in the *reduction* condition? using an analog scale from 0 (no perceptual changes of intensity at all) to 100 (very strong perceptual changes of intensity).

Participants were also informed that half had received real tDCS treatment while the other half had received sham stimulation, to verify participants' belief in the authenticity of the device used. They were then asked to indicate their belief regarding the type of stimulation they received by pressing 1 for real and 2 for sham stimulation. Finally, participants completed two questionnaires: the Short Suggestibility Scale (SSS), a condensed version of the Multidimensional Iowa Suggestibility Scale (MISS; Kotov et al., 2004), and the Spontaneous Use of Imagery Scale (SUIS; Kosslyn et al., 1998). Participants were informed that the tDCS and skin-conducting devices were non-functional only after all data had been collected for both sets of experiments, including those presented in Chapter 3 and the current section.

Analyses

The analyses conducted in this study mirrored those used in Chapter 3. Additionally, PSE values for the conditioning trials in both conditions were extracted using the same method. Datasets included in the analysis of conditioning trials' PSE values were excluded based on identical criteria as the main PSE analysis ($R^2 \geq .40$). Furthermore, catch trials were analyzed as the percentage of correct responses for each condition. A higher percentage of correct responses suggested greater attentiveness to the tactile task. Lastly, we calculated the mean perceptual ratings concerning amplification and reduction in tactile strength, along with the number of responses indicating whether participants believed they were engaged in sham or active tDCS.

4.2.2 Results

PSEs in regular i.e. standard intensity trials (variable of interest)

If the placebo manipulation was effective, we expected that the PSE in the *weak* condition would be significantly lower than the PSE in the *strong* condition and that there would be a greater separation between psychometric functions compared to the experiments in Chapter 3, due to directly contrasting manipulations of perceptual strengths. However, no significant differences were found between the PSE in the *weak* condition (M = .58, SD = .10) and the PSE in the *strong* condition (M = .56, SD = .08), z = -1.381, p = .177, r = .22 (see **Figure 6A**). **Figure 6B** presents individual PSE values under both *strong* and *weak* conditions for each participant.

PSEs in conditioning trials

Four participants were outliers due to poor goodness-of-fit threshold ($R^2 \geq .40$) in the *strong conditioning* condition. For the resting 16 participants, the PSE in conditioning trials for the *weak* condition, M = .42 (SD = .13) differed significantly from the PSE in conditioning trials for the *strong* condition, M = .71 (SD = .11), z = -3.516, p < .001, r = .62, and the psychometric function in the *strong* condition was shifted towards the right, as compared to the *weak* condition (see **Figure 6C**). This suggests that participants detected the changes in the "perceived" frequency of touches (note that we only manipulated the intensity), and consequently, perceived the actual changes in intensities between the two fingers. These results were in alignment with the predictions for the effects of perceived frequency, if intensity on the reference finger was actually stronger.

Catch trials

In trials where the frequency on the comparison finger was set to 40 Hz, participants accurately perceived the pace as faster in 90.36% of their responses. Conversely, in trials where the frequency on the comparison finger was set to 20 Hz, participants correctly identified the pace as slower in 94.23% of their responses. These results indicate that participants demonstrated a very high level of attentiveness to the tactile task.

Expectancy, suggestibility, and imagery scores

Participants were classified as average imagers (M = 38.75, SD = 8.07; based on Sample 1; Nelis et al., 2014) and average in suggestibility (M = 52.35, SD = 9.09; based on Kotov et al., 2004). The perceived touch intensity reduction rating in the *weak* condition had a mean of 43.67 (SD = 23.39), whereas in the *strong* condition, the mean was 51.90 (SD = 23.44). Of the whole sample, 16 participants believed they were involved in an active tDCS experiment, while 3 thought they were part of a sham tDCS session. One participant did not respond to the question.

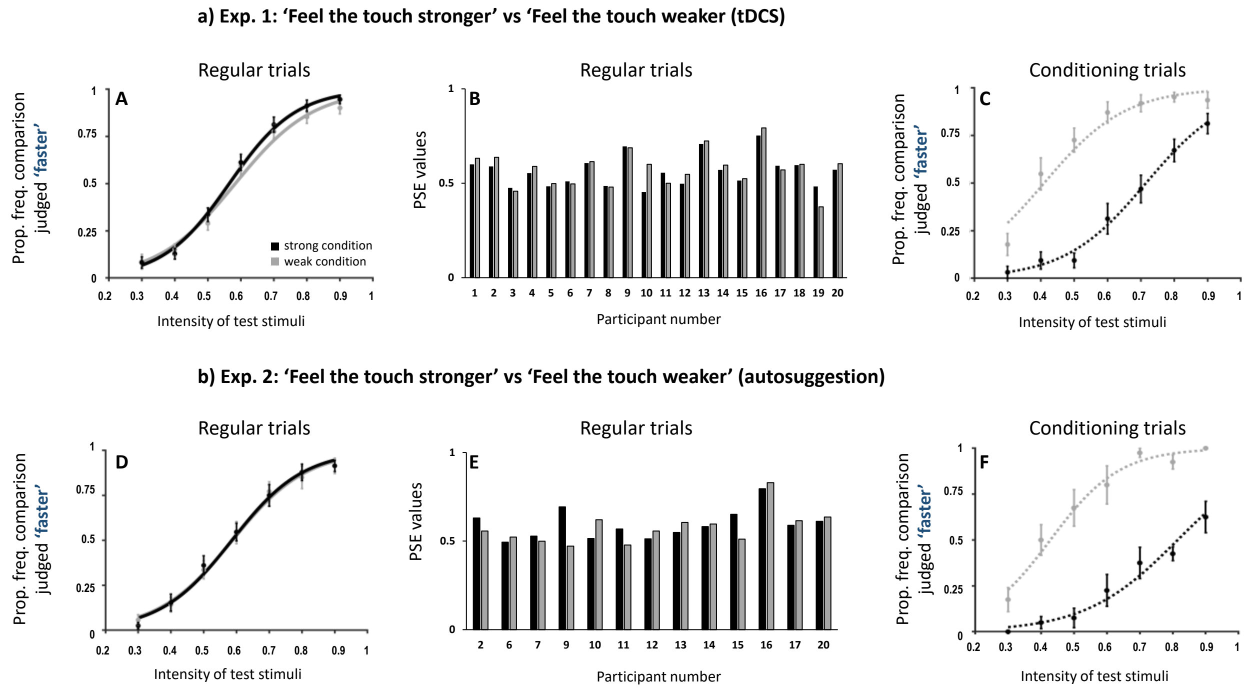

Figure 6. Overview of experimental results. The black color represents the *strong* condition, and the grey color indicates the *weak* condition. **A and D)** The continuous lines on the psychometric graphs display the results from the standard intensity trials, where the stimulus on the reference finger was always set to the same intensity (0.6). The Y-axis of the psychometric graphs shows the proportion of responses in which the touch on the comparison finger was judged to be faster than the touch on the reference finger. Note that the frequency on both fingers was always the same: 30 Hz. The X-axis indicates the intensity levels applied to the comparison finger, ranging from 0.3 to 0.9. In both Experiment 1 (placebo) and Experiment 2 (autosuggestion), there were no significant differences in frequency pace judgments between the *weak* and the *strong* conditions during standard intensity trials. **B and E)** The mean PSE values for each participant in both the *strong* and *weak* conditions. Note that graph E displays the results of participants who returned for re-testing in the follow-up experiment involving autosuggestion. **C and F)** The dashed lines represent the results from the conditioning trials only. Here, the intensity of conditioning trials on the reference finger was set at 0.8 and 0.4 for the *strong* and *weak* conditions, respectively, while maintaining a constant frequency. We observed significant differences in frequency perception, with the *strong* condition demonstrating higher frequency perception at the reference finger compared to the *weak* condition.

4.3 Experiment 2: autosuggestion (preliminary results)

Experiment 2 explored the effects of autosuggestion by employing the same paradigm as Experiment 1, but this time participants were instructed to modify their perception of tactile intensity through autosuggestion, mirroring the approach used in the experiments outlined in Chapter 3. Please note that data from only 13 participants could be analyzed. The results presented here are exploratory rather than definitive. Therefore, they should be interpreted as indicative trends rather than conclusive results.

4.3.1 Materials and Methods

Participants

All participants who took part in Experiment 1 were invited to participate in Experiment 2. 14 participants returned. The dataset of one participant was excluded from analysis due to the goodness-of-fit threshold ($R^2 \geq .40$) in the regular trials in the *weak* condition. 13 participants formed the final sample, (6 females, M age = 25.2, SD = 2.77). All participants were right-handed, (M = 93.4, range: 64.7 – 100). Given the limited sample size, these findings are considered exploratory, and definitive conclusions cannot be drawn from them.

Stimuli

All stimuli were sine waves sine wave taps, lasting 500 ms delivered by 5 channel amplifier and the tactile array systems (Dancer Design).

Procedure

The experimental procedure closely mirrored that of Experiment 1. A major difference in this experiment was that participants were asked to alter their perception of tactile intensity intentionally using autosuggestion, in the same way as in experiments of Study 1. To encourage this, at the beginning of the experiment, the experimenter clarified that the device utilized in Experiment 1 was inactive and employed as a placebo manipulation. Thus, any changes in tactile intensity on the reference finger they might have perceived were attributed to the participants' brain abilities to produce those changes. In this experiment, participants were instructed to use their mental abilities to voluntarily influence tactile perception by repeatedly thinking that the touch felt either very strong or very weak, based on the experimental condition. The experiment consisted of four parts, which were explained to participants before it started, as follows:

Frequency-intensity discrimination training

This experimental session mirrored the training conducted in Experiment 1 and all experiments in Chapter 3; however here, we used sine wave stimuli. The standard intensity for the reference finger was set at 0.6, while the intensities on the comparison finger ranged from 0.3 to 1.0 in increments of 0.1 units.

Baseline

This experimental session resembled the *baseline* condition of previous experiments, using sine wave stimuli. The intensity of the reference finger was fixed at 0.6, while the intensity on the comparison finger varied between 0.3 and 0.9. The frequency remained constant at 30 Hz, there were 98 trials.

Autosuggestion training

The training procedure for autosuggestion closely followed the methodology used in Chapter 3, with a few modifications. Participants underwent the training twice, once for both the *weak* and the *strong* conditions. There were 5 trials per condition, with touches separated by 1.5 s ISI instead of 1 s.

Main experimental session (testing the effects of autosuggestion strong vs weak)

The experimental procedure closely mirrored that of Experiment 1 using placebo, with a significant distinction: participants actively engaged in autosuggestion. In this session, they were instructed to autosuggest that touches felt weak or strong, depending on the condition, as previously done in Study 1 (see Chapter 3). Each block began with a one-minute initial autosuggestion, where participants affirmed the strength of the upcoming congruently with the experimental condition. Following this, participants indicated their expectations for altering their touch perception on an analog scale (expectancy ratings), where zero represented no belief in their ability to produce perceptual changes and 100 indicated complete confidence in their capability to effect such changes. Additionally, after each mini-block, they assessed their belief in the effectiveness of their autosuggestion (self-efficacy) in the last mini-block, using the same analog scale from Study 1. On this scale, zero indicated that they felt unsuccessful in their autosuggestion efforts, while 100 signified that they believed they were very successful in perceiving tactile intensity as stronger or weaker using autosuggestion. This approach aimed to motivate participants to invest effort into experiencing changes in their touch intensity perception. At the end of the experiment, participants answered two questions: 1) To what extent they perceived a reduction in touch intensity during the reduction blocks, and 2) To what extent they perceived an amplification of touch intensity during the amplification blocks (final self-efficacy ratings). Responses were recorded on an analog scale, where zero indicated no perceivable change and 100 represented a significant change in perception. The Short Suggestibility Scale (SSS) and the Spontaneous Use of Imagery Scale (SUIS) questionnaires were not administered in this experiment, as these ratings had already been collected in Experiment 1.

Analyses

Analyses followed the same approach as in Experiment 1. Individual beliefs regarding the successful performance of autosuggestion, collected before each block for each condition, were averaged. These means, along with the final mean self-efficacy ratings, are reported. Additionally, the mean scores for the Short Suggestibility Scale (SSS) and the Spontaneous Use of Imagery Scale (SUIS) were recalculated exclusively for the participants involved in this experiment.

4.3.2 Results

Please note that due to the limited sample size, the analyses presented here are exploratory rather than definitive. Therefore, they should be interpreted as indicative trends rather than conclusive results.

PSEs in regular, i.e. standard intensity trials (variables of interest)

No significant differences were found between the PSEs in the *weak* condition (M = .58, SD = .09) and the *strong* condition (M = .59, SD = .08), z = -.245, p = .839, r = .05 (see **Figure 6D**). **Figure 6E** presents individual PSE values under both *strong* and *weak* conditions for each participant.

PSEs in conditioning trials

Out of 13 participants, three did not meet the goodness-of-fit threshold ($R^2 \geq .40$) for the conditioning trials in the *weak* or *strong* conditions, and their data was excluded from the analysis. In the analyzed sample of 10 participants, the PSE in the *conditioning weak* condition (M = .43, SD = .10) was significantly lower than the PSE for the conditioning trials in the *strong* condition (M = .80, SD = .11), z = -2.803, p = .002, r = .63 (see **Figure 6F**).

Catch trials

In trials where the frequency on the comparison finger was set to 40 Hz, participants accurately perceived the pace as faster in 87.09% of cases. Conversely, when the frequency was set to 20 Hz, they correctly identified the pace as slower in 94.23% of instances. These results indicate that participants demonstrated a very high level of attentiveness to the tactile task.

Beliefs, self-efficacy, suggestibility, and imagery scores

Participants were categorized as average imagers (M = 38.69, SD = 6.88; based on Sample 1; Nelis et al., 2014) and showed average suggestibility (M = 53.31, SD = 9.22; based on Kotov et al., 2004). The mean perceived reduction in touch intensity for the *weak* condition was 49.42 (SD = 27.22), while the mean for the *strong* condition was 58.44 (SD = 30.18).

4.4 Discussion

The present study aimed to expand on the findings from Study 1, in Chapter 3, by comparing the effects of autosuggestion with those of a placebo. In Experiment 1, participants underwent a placebo procedure where they were misled into believing that the current delivered through tDCS applied to their scalp would affect their perception of tactile stimuli, by either amplifying or reducing the strength of perceived sensations. After Experiment 1, the same participants were invited to participate in an autosuggestion procedure, which was implemented using the same principle as the experiments outlined in Chapter 3.

The present results revealed no effects of placebo manipulation on tactile intensity perception. Equally intriguing, autosuggestion also failed to produce any noticeable effects. We believe the absence of significant findings, particularly in Experiment 2, may be attributed to several factors, with a key issue being a failure to recruit a sufficient sample size. Indeed, we included this data set for completeness in the present thesis, but conclusions from this experiment should be taken with caution, as the sample was not fully representative.

Additionally, the modifications made to the experimental paradigm may have contributed to the inability to detect significant effects. Here, to potentially enhance the effectiveness of the experimental manipulations, we introduced conditioning trials at the beginning of each mini-block, where the tactile intensity on the left finger was adjusted to be either higher or lower than the standard intensity, depending on the condition. Evidence suggests that surreptitious change in stimulus intensity can contribute to the elicitation of placebo effects (Fiorio et al., 2012; Morton et al., 2010; Voudouris et al., 1990; Wager & Atlas, 2015). For instance, Fiorio et al. (2012) introduced a conditioning procedure for the experimental group, after cream application. Specifically, in a block of trials following the cream application, the intensity of stimulation was increased, unknowingly to participants. In contrast, the control group was informed of the cream's ineffectiveness and that the intensity of stimulation would be increased. Despite the physical similarity in stimulation intensity between the two groups, the experimental group reported significantly heightened tactile sensations after the cream treatment compared to their baseline measurements, which was not observed in the control group. Furthermore, this group exhibited alterations in late somatosensory cortical components, particularly the N140 and P200 waves, following the treatment. Additionally, findings from a follow-up study conducted by the same researchers revealed that verbal suggestion alone was not enough to enhance tactile perception (at least within this experimental context), highlighting the potential significance of a conditioning procedure in the tactile domain (Fiorio et al., 2014).

The aim of introducing the conditioning trials in our study was therefore to increase the placebo effect or the autosuggested outcomes. However, this might have brought the opposite results: participants may have recognized a pattern, particularly that changes in intensity occurred solely at the start of each mini-block. Such awareness might have led them to question the effectiveness of the placebo tDCS-like device, despite most participants reporting a strong belief that they were receiving genuine tDCS stimulation. In the autosuggestion group, if participants detected this pattern but were not actively engaging in autosuggestion, they may have lost motivation and ceased to perform the autosuggestion task, which could explain the lack of differences between the *strong* and *weak* conditions.

Comparing two conditions within a single experiment, such as strong versus weak, rather than assessing each condition against a baseline, may have also contributed to the null results observed. This design likely heightened participants' expectations of perceiving larger perceptual differences between conditions. When such differences failed to materialize, participants may have struggled to detect changes in perception, leading to decreased motivation to fully engage in the placebo or autosuggestion tasks. As a result, they may have reported changes in perceived tactile intensity without truly adhering to the experimental manipulations.

Furthermore, repeating the experiment following the placebo manipulation, which failed to produce substantial perceptual differences, may have further reduced participants' belief in the efficacy of the task. This makes it less plausible that they would have engaged with the same level of effort or expectation when attempting to produce the desired effects through autosuggestion, particularly after their prior experience with a task they believed involved tDCS but turned out to be an inactive placebo leading to no significant perceptual changes.

In conclusion, although the present study did not demonstrate significant effects of placebo or autosuggestion on tactile intensity perception, it offers important insights into the complexities involved in modulating perception through top-down mechanisms and the importance of experimental parameter selection. Future research could benefit from addressing the abovementioned limitations by refining experimental protocols, increasing sample sizes, and exploring alternative conditioning strategies to enhance the efficacy of placebo and autosuggestion effects. Additionally, investigating individual differences in suggestibility, imagery, and underlying neural mechanisms might provide deeper insights into the variability in responses to such interventions. Despite the challenges faced, this study adds to the expanding literature on the influence of suggestion on perception.

Chapter 5

Study 3: Does autosuggestion influence complex body representations?

5.1 Introduction

Bodily sensations are not fixed but they constantly shift and adapt in response to changing environmental conditions. Recent research highlights the great flexibility of sensory experiences. For example, in our recent work, we showed that participants updated their perception of a "normal" body after only a few seconds of exposure to either obese or underweight bodies (Myga et al., 2024a see Annex 1 for the full article). After exploring a fat body haptically, participants perceived subsequent bodies as thinner compared to the baseline. Conversely, the same bodies felt fatter after exposure to skinny bodies. This rapid recalibration underlines the sensory system's ability to adapt dynamically to environmental input.

Complementary research highlights how even simple shifts in attention can significantly alter bodily experiences. For instance, focusing attention on the body increases tactile acuity (Cardini et al., 2011; Sadibolova & Longo, 2014; Gomez-Ramirez et al., 2016), and pain tolerance (Longo et al., 2009), and can alter skin temperature (Sadibolova & Longo, 2014). In contrast, directing attention away from the body decreases the conscious awareness of tactile sensations (Eimer et al., 2004). Moreover, mental imagery – such as imagining a protective glove or a painful lesion on the arm – reduces or enhances pain sensations, respectively (Fardo et al., 2015). Importantly, these perceptual changes do not depend upon the participant's will but represent a natural byproduct of the mental strategy used, such as attention or imagery.

Our preliminary findings from Study 1, suggest that autosuggestion can modify perceptions of tactile intensity (Myga et al., 2024b). However, these results do not allow us to generalize to potential changes into body schema perception, as tactile perceptions concerning localized body parts differ qualitatively from the processes involved in more complex body representations (Tamè et al., 2019). Building on the insights from Study 1, the current study investigates the impact of autosuggestion on complex bodily perceptions, specifically focusing on the body schema – an unconscious representation of the body's spatial properties and the relative positions of body parts, primarily informed by proprioceptive information. This schema is constantly updated as it serves to guide action and movement (Morasso et al., 2015). The main interest here is on body posture perception, specifically through the lens of the crossed-hands deficit. Traditionally, this deficit has been investigated using tactile temporal order judgment (TOJ) tasks where participants usually perform worse when making temporal judgments on crossed hands compared to uncrossed hands (Azañón et al., 2010, 2015, 2016a; Sambo et al., 2013). One standard measure in TOJ tasks is the Just Noticeable Difference (JND), which represents the shortest time interval needed to make a correct discrimination.

More precisely, when two successive tactile stimuli are applied one to each hand, responding with the hand that was touched first, is significantly impaired with limbs crossed as compared to uncrossed. Indeed, while with the hands uncrossed the JND is about 50 ms, this increases to approximately 200-300 ms with the hands crossed (Azañón & Soto-Faraco, 2007). The crossed-hands deficit has been attributed to several factors such as a conflict between the hands' position in external space and their anatomical location, an incongruence with the typical configuration of the body in an uncrossed position, or a delay in processing tactile input from anatomical space to external space (Shore et al., 2002, 2005; Soto-Faraco et al., 2004; Yamamoto & Kitazawa, 2001). Regardless of the underlying mechanism, which is beyond the scope of this thesis, this deficit offers a unique opportunity to investigate implicitly, whether autosuggestion can affect the perception of hand posture.

Whereas repetitive stimulation in the crossed-hands posture (Azañón et al., 2015) and training can reduce the crossed-hands deficit to some extent (Craig & Belser, 2006), completely eliminating it has proven to be challenging (Benedetti, 1991; Craig & Belser, 2006). Nevertheless, apart from extensive training, several manipulations can reduce it. For instance, physically increasing the distance between the hands has been shown to alleviate the deficit (Lakatos & Shepard, 1997b; Shore et al., 2005). Additionally, imagining the hands as uncrossed significantly reduces the deficit, even when proprioceptive information remains unchanged (Gallace & Spence, 2005; Lorentz et al., 2022). Moreover, positioning uncrossed rubber hands above participants' real crossed hands, which are hidden from view, improves performance when the rubber hands move in synchrony with the real hands, and a reinforcing sense of agency is introduced (Azañón & Soto-Faraco, 2007).

In this study, we combined the rubber hand illusion (RHI) with the crossed-hands deficit phenomenon. The RHI is a well-documented perceptual phenomenon in which individuals experience a sense of ownership over an artificial hand when visual and tactile inputs are synchronized (Botvinick & Cohen, 1998). However, here, we did not induce the RHI through the traditional method of synchronous stroking. Instead, we instructed participants to use autosuggestion (as defined in Chapter 2) to induce a sense of ownership over rubber hands. Specifically, participants were asked to repeat phrases like "These are my hands" and "They feel like my hands" while looking at uncrossed rubber hands placed above their real (unseen), crossed hands (see **Figure 7a**). Participants alternated between the autosuggestion task and a tactile TOJ task.

We hypothesized that successful autosuggestion would lead participants to transform tactile stimuli from a somatotopic reference frame (aligned with the skin surface) into an external spatial reference frame defined by the visual-spatial position of the rubber hands. Given that the rubber hands are placed in an uncrossed posture, this should facilitate the localization of tactile stimuli, as it has been previously demonstrated to be easier when the touched limbs are placed in a canonical position (i.e., right hand on the right side of the body's midline and left hand on the left side). This process, termed tactile remapping, involves the integration of tactile, proprioceptive, and visual information, and in the present study should further be reinforced here by suggestions that the rubber hands belong to the participant.

We also included two control conditions for comparison. In the *autosuggestion other* condition, participants performed a similar task but suggested that the rubber hands belonged to a close friend of the same gender. We expected a decrease in TOJ performance in this condition compared to autosuggestion self, as the suggestion that the hands belonged to someone else would impede the perceptual integration of the rubber hands into the participant's body representation.

The second control condition (i.e., *no autosuggestion* condition) involved participants looking at a pair of rubber hands placed in anatomically implausible positions (e.g., palms upwards, pointing sideways, see **Figure 7b**) without autosuggestion. Given the implausible positioning and that no integration attempts into the body schema were made, we predicted poor performance by participants comparable to that usually seen in the classical TOJ tasks with crossed hands.

To quantify the magnitude of the crossed-hands deficit in the TOJ task, we used JNDs as our measure of interest. The differences in the JNDs between conditions may serve as an index of the crossed hands deficit, with lower JNDs indicating better performance (Azañón et al., 2016a). We hypothesized that JNDs would be significantly lower in the *autosuggestion self* condition, followed by JND in the *autosuggestion other*, and lastly in the *no autosuggestion* conditions. This pattern would be predicted as showing evidence that self-directed autosuggestion effectively mitigates the crossed-hands deficit.

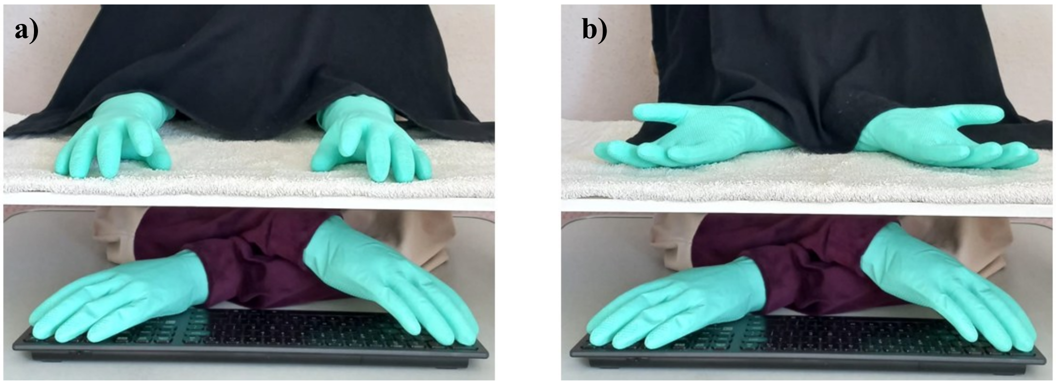

Figure 7. Frontal view of the experimental setup. Rubber hands were placed on the platform and above participants' real uncrossed hands in both conditions. **a)** In the *autosuggestion self* and *autosuggestion other* conditions rubber hands were placed in an uncrossed position. **b)** In the *no autosuggestion* condition rubber hands were placed in an anatomically implausible position, palms up, pointing sideways. Please note that this illustration focuses solely on depicting the positions of rubber and real hands. In the actual experiment, tactile stimulators were specifically placed on the dorsal middle phalanges of the index fingers of both the real and rubber hands.

5.2 Materials and methods

Participants

28 participants took part in the experiment. Outliers were defined as data points falling below 2.5 standard deviations from the mean. Any values less than this threshold (mean - 2.5*SD) were excluded from the analysis. Based on this, four participants were considered outliers and were removed from the analysis. 24 participants formed the final sample (13 females, M age = 27.42, SD = 3.93). 20 were right-handed, 3 were left-handed and 1 was ambidextrous (M = 70.59, range: - 89.35 – 100). Participants signed informed consent, were naïve, and were paid for their participation. The procedures were approved by the ethics committee at Otto-von-Guericke University Magdeburg.

Stimuli

The stimuli were sine wave taps lasting 15 ms delivered at suprathreshold intensity delivered by 5 channel amplifier and the tactile array systems (computer-controlled devices for driving an array of tactors; Dancer Design). Stimuli were delivered to the middle phalanges of index fingers. Stimuli were presented using a Matlab version and Psychtoolbox (Brainard, 1997; Kleiner et al., 2007).

Experimental procedure

Participants wore household cleaning gloves with holes on the dorsal side of the index fingers to allow the placement of the stimulators. The gloves were identical to those put on the rubber hands. This was done to minimize visual differences in shape and skin tone and to facilitate the embodiment of rubber hands.

The experiment began with a demonstration to ensure participants understood the task. Specifically, the experimenter touched participants' index fingers one after another and asked them to indicate which finger received the first touch. Following this demonstration, participants underwent a proper training session with real tactile stimuli.

Training session of the main experiment

Before starting the actual experiment, participants performed a training task with hands uncrossed and occluded from view, to make sure they understood the instructions for the TOJ task. Two sequential touches were applied: one to the dorsum of one index finger, followed by a touch on the dorsum of the second index finger, with the order of touches randomized. The tactile stimuli were delivered with 8 different stimulus onset asynchronies (SOAs) between the two taps: ±1.5 s, 0.8 s, 0.2 s, and .04 s (with negative values indicating the left index finger was touched first). The task was to press a button underneath the finger that received the first touch. Participants were instructed to respond by simply pressing a button on the keyboard with the finger that was touched first, without giving thought to whether it was the right or left hand. They were also informed that they should only respond once both touches had been felt and that accuracy, rather than speed, was the priority. No time limit was imposed on responses. Participants were only allowed to proceed to the main experiment after correctly identifying the order of the stimuli in at least 70% of trials during training. Out of 24 participants, 20 required only one practice session to meet this criterion, two participants completed two sessions, and one participant needed three practice sessions before progressing. Additionally, one participant requested a second practice session despite having achieved an 80% accuracy rate in the first session. During training the rubber hands were hidden from view.

Main experimental session

The experiment comprised three conditions: 1) *Autosuggestion self*, 2) *Autosuggestion other*, and 3) *No autosuggestion* (rubber hands in implausible positions). The order of these conditions was counterbalanced using a Latin-square design to control for sequencing effects. The TOJ task remained the same across all conditions. The entire experiment consisted of 468 trials, with 156 trials per condition. Every 13th trial involved participants engaging in autosuggestion (see details below), after which the tactile task resumed with the largest SOA of 2.5 seconds to refocus their attention to the tactile task. Twelve such large SOAs per condition were excluded from the analysis. The analyzed data included SOAs featuring two taps separated by intervals of ±1.5 s, 0.8 s, 0.2 s, and 0.04 s, resulting in 24 trials of each SOA per condition.

In all conditions, a pair of rubber hands was placed on a platform above the participants' real hands. In the *autosuggestion self* and *autosuggestion other* conditions, the rubber hands were positioned palms down and uncrossed (in an anatomically congruent or canonical position, see **Figure 7a**). In the *no autosuggestion* condition, the rubber hands were placed palms up, pointing to the sides (in an anatomically implausible position, see **Figure 7b**). In the *autosuggestion self* condition, participants were asked to autosuggest by repeating phrases mentally, such as “These are my hands” and “They feel like my hands” to induce the feeling of ownership over the rubber hands. In the *autosuggestion other* condition, participants repeated phrases affirming that the rubber hands belonged to their best friend of the same gender. During the *no autosuggestion* condition, participants were instructed to simply observe the rubber hands without engaging in any specific thoughts.

Each block of trials began with a 30-second period dedicated to autosuggestion (or waiting in the *no autosuggestion* condition), repeated after a mid-block break. Additionally, participants engaged in autosuggestion for 12 seconds every 13th trial (12 times per block). Participants performed the tactile TOJ task only between autosuggestion periods. During the TOJ task, they turned their visual focus from the rubber hands toward the fixation point in the middle between the rubber hands. In the *no autosuggestion* condition, instead of reiterating autosuggestive thoughts, participants were instructed to wait for the tactile task to begin. The experimenter verbally instructed participants when to start autosuggestion or the wait period. Once participants felt the first touch, they knew the tactile task commenced. The tactile task in all conditions began with a large SOA of 2.5 s between the two touches (this initial touch was not analyzed).

At the end of the experiment, participants completed a post-experiment questionnaire designed to gain insights into their mental strategies during the experiment, particularly regarding their use of autosuggestion. The questionnaire included the following questions: 1) How did you do your autosuggestion? Which autosuggestion was easier – the self or the other person, why? 2) Which condition was easiest for you: autosuggesting that rubber hands are yours, autosuggesting that rubber hands belong to your best friend, or just looking at rubber hands and why? 3) In which condition tactile task was the easiest and why? 4) On the scale from 0 = not at all, to 10 = very much, did you create pictures in your head? 5) On the scale from 0= not at all, to 10 = very much, did you create words in your head?

Analyses

Analyses were performed in MATLAB version R2023a (MathWorks). The data was analyzed using psychometric fitting to calculate the just noticeable difference (JND, the time interval at which participants are correct in 75% of responses). To calculate JNDs, participants’ responses were recalculated as a proportion of responses “the finger was touched first” across all SOAs and were fitted to a logistic function. Only data that met the goodness of fit criterion (see above) were included in the final analyses. Individual JNDs were then submitted to a one-factorial repeated measures analysis of variance (rmANOVA), with the condition as a within-subject factor.

5.3 Results

JNDs

An ANOVA with the repeated measure factor of condition showed no significant differences in JNDs across conditions: $F(2, 46) = 1.030$, $p = .365$, partial $\eta^2 = .043$ (*autosuggestion self*, M = 213.81, SD = 153.96, *autosuggestion other*, M = 194.49, SD = 132.63, *no autosuggestion*, M = 178.16, SD = 129.78; see **Figure 8**). These results suggest that our experimental manipulations were not effective.

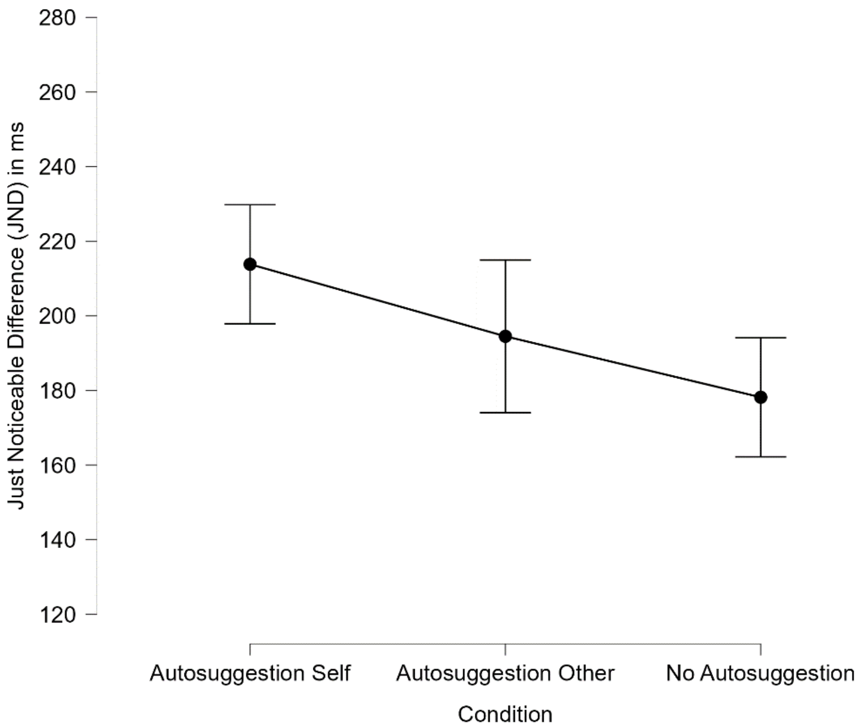

Figure 8. Overview of experimental results. The black dots represent JND values in *autosuggestion self*, *autosuggestion other*, and *no autosuggestion* conditions. Error bars represent standard errors.

Task strategies overview from follow-up questionnaires

Due to a technical error, the answers of one participant were not saved and the summary includes responses from 23 participants. In examining the easiness of autosuggestion between the *self* and the *other* conditions, 57% of participants found it easier to assert ownership of the rubber hands by claiming they belonged to themselves. They reported a significant sense of control over their sensations, which facilitated the integration of the rubber hands into their body image. About half of this group employed verbal autosuggestion, whereas the rest used imagery, or combined both techniques. In contrast, 13% of participants preferred suggesting that the rubber hands belonged to someone else, often reporting a lack of control over the rubber hands, while another 13% did not specify which condition was easier, focusing instead on their approaches to autosuggestion.

When asked which out of the three conditions was the easiest for them (autosuggestion self, autosuggestion other, or no autosuggestion), the majority of participants (approximately 77%) found it easiest to simply look at the rubber hands, due to a reduced mental effort and better focus on tactile stimulation. A smaller group (about 23%) preferred the *autosuggestion self* condition, emphasizing feelings of control, personal perspective, and the use of imagery. Additionally, a few participants (approximately 15%) found it easiest to autosuggest that the hands belonged to their best friend, attributing this preference to a strong sense of closeness to that person, which made the suggestion more believable.

When assessing the ease of the tactile task between the three conditions, 22% of participants found it simplest while merely observing the rubber hands, due to the reduced mental effort. Conversely, 13%

indicated that the tactile task was easier when autosuggesting that the rubber hands belonged to someone else, with the rest expressing that this approach allowed them to focus better on their own tactile sensations. In terms of cognitive engagement, participants reported mean scores of 4.79 out of 10 (SD = 2.90) for imagery use and 8.53 out of 10 (SD = 1.61) for the use of verbal autosuggestion, reflecting a greater reliance on verbally repeating thoughts during the autosuggestion tasks.

5.4 Discussion

This study investigated whether autosuggestion could influence the perceptual integration of incongruent body postures into their body schema measured by reducing the crossed-hands deficit in a tactile TOJ task. Specifically, participants used autosuggestion to assert that rubber hands, placed in an uncrossed position above their real, crossed hands (occluded from view), belonged to them. We hypothesized that autosuggestion would lead participants to incorporate the rubber hands into their body schema. We predicted that this would improve performance on the TOJ task by reducing the conflict between visual and proprioceptive input, as compared to other conditions: autosuggestion that the rubber hands belong to participants' best friend (*autosuggestion other* condition), or simple observation of the rubber hands placed in the anatomically implausible position (*no autosuggestion* condition).

The expectation that autosuggestion would alleviate the crossed-hands deficit was based on research showing the significant role of visual input in spatial remapping during TOJ tasks (Gallace & Spence, 2005; Soto-Faraco et al., 2004). The crossed-hands deficit is primarily driven by a conflict between proprioceptive and visual inputs, as evidenced by the fact that blind individuals do not show this deficit unless they acquire blindness later in life (Röder et al., 2004). We hypothesized that autosuggestion – by visually aligning the rubber hands in an uncrossed position – would lead to congruence between external (visual) and internal (proprioceptive) reference frames, thus mitigating the crossed-hands deficit. We also hypothesized that this effect would be greater in the *autosuggestion self* condition, where participants tried to embody the rubber hands into their body schema, compared to the *autosuggestion other* condition, where participants aimed to create separation between the rubber hands and their own body. Finally, because the hands were placed in an anatomically implausible position in the *no autosuggestion* condition – making it difficult for participants to incorporate them into their body image – and there was no intentional mental effort to do so, we expected participants to perform the worst in this condition, similar to the performance typically observed in TOJ tasks with crossed hands.

Azañón and Soto-Faraco (2007) provided key insights into the modulatory effects of external visual stimuli on the crossed-hands deficit, demonstrating that participants' TOJ performance improved by approximately 157 ms when they viewed uncrossed rubber hands placed over their crossed real hands, compared to viewing crossed hands. However, the effectiveness of this improvement depended on several conditions, including prior visuo-motor training, which helped establish a mapping between the real and rubber hands. Specifically, participants' real movements with crossed hands were linked to the movements of the rubber hands placed above them. These movements were anatomically congruent – for example, pressing a button with the real right hand (located on the left side of space due to crossing) corresponded to pressing a button with the uncrossed right rubber hand (placed on top, on the right side of space). Nonetheless, the performance improvement when seeing uncrossed rubber hands was only apparent when this mapping was frequently executed during the task, such as by actively trying to switch off lights presented at the rubber hand fingertips by moving the real hands. Therefore, mere anatomical congruency during movement was insufficient as repeated interaction was necessary to improve performance. Moreover, mental imagery of uncrossed hands, while blindfolded, has been shown to reduce the crossed-hands deficit by aligning internal and external reference frames (Lorentz et al., 2022). Thus, we expected that autosuggestion in our study would similarly create an illusory alignment between the rubber and real hands, particularly in the *autosuggestion self* condition.

Contrary to our expectations, the analysis revealed no statistically significant differences between the three experimental conditions. Even more intriguingly, the numerical trends in participant responses suggested a pattern that was opposed to our initial hypotheses. Specifically, participants performed numerically better without any type of autosuggestion, while their performance was numerically least effective when they were instructed to autosuggest that the rubber hands belonged to them.

One of the possible reasons for the insignificant findings may be because of the cognitive complexity introduced by the combination of autosuggestion and the TOJ task. Participants were required to engage in autosuggestion at specific intervals and switch over to the tactile task afterward. Although this alternation was intended to reduce the mental load of performing both tasks simultaneously (based on informal feedback from participants taking part in our previous studies), it may have restricted the effects of autosuggestion. It may be that the short intervals of autosuggestion were not long enough to induce significant changes in body schema, changes which would then carry over into the tactile task for which participants were instructed to shift their visual attention from their hands to the fixation point between their hands. Indeed, we have previously emphasized the need for sustained and focused mental effort to produce significant changes in bodily percepts (Myga et al., 2024b). Also, in our previous studies (Study 1 and 2), participants were performing the tactile tasks in parallel with autosuggestion (see Chapters 3 and 4, and Myga et al., 2024b). Moreover, self-reports from participants indicated that the *no autosuggestion* condition was the easiest for them to perform the tactile task. They explained that this condition was without any additional cognitive load, and they could focus entirely on the tactile stimuli while ignoring the rubber hands. Meanwhile, both autosuggestion conditions required additional mental effort and alternating attention between autosuggestion and tactile tasks.

Another reason that may have contributed to the null results is the absence of matching tactile-visual synchrony, which in the past has been suggested as an integral factor necessary for inducing the rubber hand illusion (Botvinick & Cohen, 1998). While sham tactile stimulators were attached to the rubber hands to enhance the illusion, the absence of any actual synchronous visual stimulation (such as simultaneous touch on both the real and rubber hands by the experimenter's hands (Botvinick & Cohen, 1998) or more relevant here – motor action visible on the rubber hands – likely limited participants' ability to fully embody the rubber hands. Thus, the proprioceptive input from the real hands did not map the tactile stimuli onto the visually presented rubber hands. Consequently, the proprioceptive feedback from participants' actual hands was not capable of mapping the tactile stimuli onto the visually presented rubber hands.

This interpretation is consistent with findings by Azañón and Soto-Faraco's (2007), commented above, where participants' real hands were connected to the rubber hands via pulleys, creating an active visuo-motor link between the real and rubber hands. Such a mapping was essential for the significant effects reported in their study but was absent in our experimental design. Without a similar visuo-motor congruency, participants in this experiment may have struggled to integrate the visual appearance of the rubber hands with their proprioceptive sensations. Yet, if we employed such visuo-motor connections in our paradigm, a question would arise, whether the effects were due to autosuggestion as earlier defined (Myga et al., 2022). Indeed, we assume that autosuggestion is a process overriding actual perception, which conflicts with the autosuggest content. Therefore, following this definition, we should be able to observe the desired effects of autosuggestion, which was not the case. Introducing external manipulation to help the effects to emerge, even if successful, would no longer reflect the pure effects of autosuggestion.

Another factor contributing to lack of differences between the *autosuggestion self* condition and the other two conditions may lie in the conceptual framing of the autosuggestion task, which was very distinct from what others did using mental imagery, a top-don strategy related to autosuggestion. Specifically, Lorentz et al. (2022) blindfolded participants who then received vibrotactile stimuli via bone-conducting vibration cubes held on each hand. Participants were asked to report which hand received the vibrating stimulation first while imagining their hands being uncrossed. Whereas Lorentz and colleagues relied on imagery that the *real hands* were in an uncrossed position (while crossed), our task involved suggesting that the *rubber hands* were a part of the body, without explicitly addressing how participants should perceive the presence of their real, crossed hands. In more detail, participants in our experiment were instructed to use autosuggestion phrases such as “These are my hands” and “They feel like my own hands” but they were not given explicit instructions about how to handle the proprioceptive dissonance between their real hands and the rubber hands. In other words, instead of autosuggesting that participants’ *real hands* are getting close in position to the *rubber hands*, where the emphasis would be on changing proprioceptive information about their own part of their body, as it was done in the study by Lorentz and colleagues (2022), we did not mention anything about their *real hands*. This lack of specificity may have led to a diverse range of cognitive strategies across participants, further contributing to null results. A follow-up experiment instructing participants to feel that their crossed hands are merging with the uncrossed rubber hands during autosuggestion could be an alternative helping to shed more light on the present results.

Following the logic in the previous paragraph, we could interpret our findings in an alternative way, which is that autosuggestion might have been effective in this experimental paradigm but in an unintended way. The instructions guided participants to embody the rubber hands into their own or another person’s body image, but no guidance was given regarding how to maintain awareness of their real hands. Consequently, participants who concentrated on embodying the rubber hands into their own bodies might have dissociated from their real hands. It could reduce their awareness of tactile sensations in their real hands, leading to the persistence of the crossed hands deficit. Indeed, one participant reported that this is exactly what happened in their case. Introducing an additional tactile task in a follow-up experiment to test attentional deployment, similar to the principle used in Study 2 with catch trials, could help to cast light on this possibility.

Also, several methodological factors might have contributed to the null findings. First, the physical contact between participants’ crossed hands (resting on each other) may have reduced the potential effects of the manipulations. In contrast, prior studies (e.g., Azañón et al., 2016b) did not involve such physical contact, which may have allowed for clearer distinctions between the internal and external reference frames. In the follow-up experiment outside of the scope of this thesis, we explore this possibility together with revised instructions, to provide more explicit guidance on how to resolve proprioceptive conflicts during autosuggestion. Additionally, we include training sessions to establish a visuomotor link between real and rubber hands, similar to the methods used by Azañón and Soto-Faraco (2007).

In summary, this study did not find any significant effect of autosuggestion in reducing the crossed-hands deficit in a tactile TOJ task. This suggests that embodying the rubber hands through mental strategies did not translate into improved performance. Although some participants reported a subjective sense of control and ease when autosuggesting that the rubber hands were their own, such experiences failed to produce the expected reductions in the deficit. The fact that the crossed-hands deficit resisted cognitive interventions like autosuggestion suggests that more substantial modifications to the experimental design may be necessary to address the conflicts between proprioceptive and visual reference frames. Future research should continue to investigate the potential of autosuggestion, to better capture the complex interactions between body schema, cognitive load, and sensory integration.

Chapter 6

Study 4: Autosuggestion and visual imagery bias the perception of social emotions

This chapter is based on content originally published in "Myga, K. A., Longo, M. R., Kuehn, E., Azanon (2025). Autosuggestion and Mental Imagery Bias the Perception of Social Emotions. *bioRxiv*. https://doi.org/10.1101/2025.01.09.632121". While most of the chapter has been extensively rewritten, a few sections, including text and figures, may be identical to the published work to ensure the accuracy and integrity of the original findings.

6.1 Introduction

Cognitive processes that effectively modulate emotion perception are of great interest for psychological and clinical research. Different methodologies exist to actively modulate perception, such as contextual cues (Reschke & Walle, 2021), hypnosis (Zhang et al., 2024), or mental imagery (Diekhof et al., 2011). In this thesis, the main interest is on autosuggestion, which we argue is a phenomenon that deserves to be explored in more detail (Myga et al., 2022, 2024b). In our previous studies, we found that individuals often report the use of mental imagery during autosuggestion. For that reason and because autosuggestion and mental imagery are the two processes that can be applied most flexibly given that no other, external person is needed (as in suggestion and hypnosis), and no specific equipment or environment needs to be used (as in meditation), this chapter compares the effects of autosuggestion with those of mental imagery.

Consequently, in our approach, we follow the definition of autosuggestion introduced in Chapter 1. Specifically in this context autosuggestion reflects a process where participants internally repeat suggestions aimed at shaping their perception of emotions in another person. Imagery, on the other hand, is defined as a process where perceptual information is assessed from the memory and results in re-creating perceptual experience in the absence of sensory input (Kosslyn et al., 2001; Pearson et al., 2013). This process relies on four key abilities: image inspection, offline image generation, mental image transformation, and mental image retention (Kosslyn et al., 1995).

With respect to autosuggestion, little is known about the effect of the intentional and internal reiteration of thoughts (e.g., "She is happy/sad") on the subsequent perception of emotions. Previous studies have reported the beneficial effects of reiterating thoughts related to desired health outcomes (Sari et al., 2017; Shilpa et al., 2020). For instance, acutely ill geriatric patients reported greater quality of life after a one-month autosuggestive procedure (Sari et al., 2017). These effects were accompanied by physiological changes, such as increased cortisol levels, reaching the norms observed in healthy adults. Other studies have shown the effects of autosuggestion-like procedure on devaluating unhealthy snacks on eating behavior (Ludwig et al., 2014) and supported the outcomes of other mental techniques such as autogenic training, a psychophysiological form of therapeutic and relaxation technique (Schlamann et al., 2010).

The effect on emotion perception, however, was not in the focus of autosuggestion research, and the potential effects of autosuggestion have not yet been compared to mental imagery. In previous chapters, we have shown that autosuggestion modulates the intensity of tactile perception at the hand (Chapter 3; Myga et al., 2024b); however, also this investigation did not focus on the emotional aspect of tactile perception but on neutral, non-emotional touches. Nevertheless, Study 1 shows that autosuggestion can be used in a standard experimental setting to modulate participants' perception dynamically and hence highlights its potential applicability to also modulate emotion perception.

Concerning mental imagery, exposure to visual imagery created in the "inner eye" has been shown to influence subsequent perception of emotions. For instance, Zamuner and colleagues (2017) demonstrated contrastive aftereffects, in which prolonged imagery of a face displaying one of six basic emotional expressions (anger, disgust, fear, happiness, sadness, or surprise) led to subsequent test faces of the same emotion, but with weaker valence, being perceived as more neutral. These results were similar to those obtained with adaptation to real emotional faces, albeit weaker in magnitude.

Here, we investigate the modulation of emotion perception via both autosuggestion and imagery. This allows us to directly compare the effectiveness of both approaches to modulate emotions in desired directions, which may have important clinical implications. We focus on social emotion perception given that well-controlled experimental setups exist on emotion perception when observing faces (Butler et al., 2008; Sou & Xu, 2019; Webster et al., 2004; Yuan et al., 2024). In addition, the ability to modulate social emotion perception is an important skill, and many clinical interventions in psychiatry target this function in patients (Saccaro et al., 2024). People with depression (Bourke et al., 2010) and those on the autism spectrum (Harms et al., 2010) for example, display negative biases in their emotion recognition. Furthermore, even in healthy troubled adults, there is a tendency toward negative bias in emotion perception. In one study, Penton-Voak and colleagues (2013) used a modified feedback paradigm to experimentally bias the perception of ambiguous faces as happy rather than angry in healthy adults and adolescents at risk of a criminal offense. Participants were given feedback that faces that had been judged as angry expressed a happy emotion. After the procedure, participants in the "modified feedback group" reported lower degrees of anger in their face ratings as compared to participants in the "accurate feedback group". Interestingly, within the same study, similar results were found in violent offenders serving time in prison (Penton-Voak et al., 2013). These findings underscore the potential of interventions that can bias social emotion perception.

In the present study, we use an adaptation paradigm, wherein participants are briefly exposed to a facial expression (suggested or imagined), to investigate cognitive processes that modulate subsequent social emotion perception. Specifically, we examine the effects of autosuggestion (Experiments 1a and 1b) and mental imagery (Experiment 2) and compare these to the influence of emotionally charged words (Experiment 3). Additionally, we contrast these findings with the effects of direct exposure to actual emotional facial expressions (rather than imagined or suggested), known to produce contrastive aftereffects (Experiment 4, "perceptual aftereffect"; Rhodes et al., 2010). We aim to determine 1) If autosuggestion and mental imagery can be used by participants to bias emotional face perception, 2) Whether this effect is driven by response bias, and 3) Whether effect sizes are comparable to those of perceptual aftereffects.

More specifically, in Experiment 1a, participants viewed a neutral female face and were instructed to use autosuggestion to perceive this face as happy or sad, repeating phrases such as “She is happy” or “She is sad”. They then rated the emotional valence of a subsequent emotional face ranging from very sad to very happy. In Experiment 1b, instructions were modified to minimize imagery use. In Experiment 2 we asked participants to imagine a previously seen neutral face as very happy or very sad after the face had disappeared from view. This involved creating visual representations in the “mind’s eye” of the neutral face stored in short-term memory and transforming it to express happiness or sadness without the actual image present, as described by Kosslyn and colleagues (1995). Experiment 3 used “HAPPY” or “SAD” words as adaptors alongside a neutral face to control for cognitive expectations (Nichols & Maner, 2008; Orne, 1962), such as the anticipation that viewing happy faces would predispose individuals to perceive more happy faces. This experiment paralleled the association between an emotion and an image in the adaptation phase of the preceding experiments but did not involve a deliberate intention to perceive or mentally create a happy or sad face. Finally, Experiment 4, involved direct exposure to extreme facial expressions to confirm the expected contrastive aftereffects (Ellamil et al., 2008; Pell & Richards, 2013; Ryu et al., 2008; Zamuner et al., 2017) and compare effect sizes across paradigms.

Together, we present a series of five experiments designed to investigate the effect of different cognitive mechanisms to modulate social emotion perception. We analyzed both the direction and strength of these effects while assessing the relative effectiveness of these techniques. The results of this study aim to identify potential applications for the modulation of social emotions to potentially transfer such techniques to clinical use.

6.2 Experiment 1a: autosuggestion

Experiment 1a investigates whether autosuggestion biases the perceived emotional valence of an observed face in the direction of happiness or sadness. Specifically, participants were asked to perceive a neutral female face presented on the screen as happy or as sad while reiterating the respective thought (e.g., “The face looks happy”).

To determine the desired sample size, we based our calculations on the results of Zamuner and colleagues (2017). They compared aftereffects produced by *perception*, *mental imagery*, and *baseline* condition for six emotions: happy, sad, afraid, angry, disgusted, and surprised. We considered the effect size of the main effect of expression, which in their study was partial $\eta 2 = .359$. We first converted their partial $\eta 2$ effect size to Cohen’s d, which was equal to $d_z = .73$. Next, we conducted a power analysis using G*Power version 3.1.9.7 (Faul et al., 2007). We set the alpha level to .05 and power to .8, which indicated a sample size of 17 participants was needed. However, we tested a few additional participants to account for the possibility of exclusions due to unforeseen issues, such as incomplete data or outliers.

6.2.1 Materials and methods

Participants

Altogether 23 participants were tested, of whom 5 participants were excluded from the analyses. Exclusion was determined by the number of test trials in which participants were presented with one extreme of the stimulus spectrum – either the extremely happy morphed face (0) or the extremely sad morphed face (99) – for more than 50% of the trials in one staircase (see exclusion procedure below), compromising the intended variability in the test stimulus presentation. This occurred because some participants consistently indicated that the saddest face appeared closer to happy, and vice versa, leading to a strong bias in their responses. 18 participants formed the final sample (7 females, M age = 25.56

years, SD = 2.99). All participants had normal or corrected-to-normal vision and were naïve to the purposes of the experiment. 16 participants were right-handed and two were ambidextrous (M = 86.08; range: 46.70 – 100; Edinburgh Handedness Inventory, Oldfield, 1971). Participants gave written informed consent for participation and were paid for their attendance. The procedures of this study were approved by the ethics committee at Otto-von-Guericke University Magdeburg, Germany (ethics number 01/19). Both the experimenter and the participants communicated in English. Each participant was tested individually.

Stimuli

Test stimuli were composed of two female facial expressions of a single identity from the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist et al., 1998) representing happy: AF29HAS and sad: AF29SAS emotions. These images were first cropped in a black oval mask (size 297 x 411 pixels) to remove hair using GNU Image Manipulation Program, GIMP version 2.10.32. Next, the images were converted into grayscale. The WinMorph 3.01 morphing tool was used to create a continuum of test stimuli transitioning in the range between happy (stimulus value 0) and sad (stimulus value 99). There were altogether 100 test stimuli created in the morphing step of one unit. Note, that the morphed levels corresponded to the relative mixture of the two stimuli, and not the perceived valence. In other words, a 49% morph represents an equal blend of the two faces, but may not be perceived as neutral or equally happy and sad. The perceived emotion depends on the criterion, the observer's sensitivity, and the specific faces used to create the morphs. Test stimuli were the same in all four experiments. For an example of test stimuli, see **Figure 9** (a full set of stimuli can be found on Open Science Framework; OSF: https://osf.io/wk9xq/?view_only=aabe0f707ce243e180c1ed34a8d0bfc7). As an adapting stimulus, we used a neutral facial expression of the same identity selected from the KDEF database (Lundqvist et al., 1998): AF29NES (see **Figure 10b**). This image was pre-processed the same way as the test stimuli. The selection of the test stimulus on each trial was determined by a Bayesian adaptive algorithm QUEST (Watson and Pelli, 1983), based on the history of previous responses, and implemented using the Quest toolbox distributed as part of Psychtoolbox (Brainard, 1997; Kleiner et al., 2007).

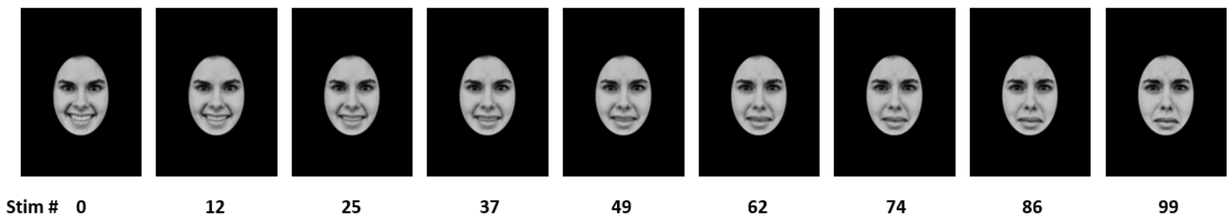

Figure 9. Example of test stimuli. Test stimuli #0, 12, 25, 37, 49, 62, 74, 86 and 99. Test stimuli were generated using the WinMorph 3.01 morphing tool, transitioning between a happy face (Stimulus #0) and a sad face (Stimulus #99), in the steps of one unit. The morphed levels represent the relative mixture of the two original stimuli. It is important to note that these levels correspond to the proportion of each original face in the blend, rather than the perceived emotional valence. A 49% morph is an equal blend of the happy and sad faces but may not necessarily be perceived as neutral or equally happy and sad.

Experimental procedure

Participants were first presented with an information sheet to familiarize them with the concept of autosuggestion and a description of the trial structure of the experiment. They were instructed to generate and reiterate thoughts affirming that the face presented on the screen appeared either happy or sad, depending on the experimental condition. In addition, to potentiate the process of autosuggestion, they were encouraged to interpret ambiguous visual elements on the screen, particularly around the mouth and eyes, as indicative of the targeted emotional expression. Specifically, they were instructed to notice that the mouth corners are pointing upwards or that the formation of wrinkles around the eyes indicates a happy emotion, while mentally repeating the sentence “She is happy”. In addition, participants received verbal guidance and engaged in exercises under the experimenter’s supervision. To train on the autosuggestion task, participants looked at the neutral facial expression and tried to autosuggest that this face looked happy or sad, respectively. Subsequently, participants underwent comprehensive training for the entire experimental task. Specifically, they were shown the adapting and test stimuli and were explained which ones to autosuggest, and which ones to judge as happy or sad. This training was a shortened version of the actual experiment. The experimenter emphasized the importance of avoiding visual imagery or mental pictures during the procedure, explaining that imagery is a separate mental process that could influence the results. All participants confirmed their understanding of this instruction.

The main experiment consists of two conditions, labeled after the elicited emotion perception: *happy* and *sad*, with the order counterbalanced across participants, separated by a short untimed break in the middle. The only difference between the conditions was which emotion was autosuggested. Participants were seated approximately 56 cm from the screen. The stimuli were shown on a 24.4-inch monitor (resolution: 1920 x 1080 pixels; refresh rate: 59.940 Hz), on a black background. Stimuli were presented at a visual angle of approximately 17.26 degrees and were centered on the screen. Stimuli were presented using Psychtoolbox (Brainard, 1997; Kleiner et al., 2007), running on MATLAB (Mathworks, Natick, MA).

Figure 10 (see below) illustrates an experimental trial. Participants were informed that each trial involved two tasks: autosuggestion and the judgment of the test stimuli. In the first task, participants were instructed to autosuggest that the face looked very happy or very sad. The second task required them to indicate whether the subsequently seen face looked closer to happy or closer to sad. Each trial began with a blank screen for 0.5 s. Next, a neutral face was shown for 6 s. This was followed by a green cross for 1 s, indicating the start of task 2 and the subsequent 0.5 s presentation of the test face stimulus. Each test stimulus was selected by the QUEST adaptive psychometric procedure (Watson & Pelli, 1983), from 100 possible test faces (morphed faces of happy and sad expressions of the same female face, see above). QUEST adaptive psychometric procedure adjusts stimulus presentation based on participants’ responses to estimate a threshold level in this case of 75%. The screen remained blank until the participant responded by pressing the left or right arrows, for sad and happy, respectively. Once a response was given, a white fixation cross appeared, indicating the end of the present trial and the start of the next trial. Participants were told that indicating emotion perception in the test stimuli was an independent task from the autosuggestion task. Subsequently, the judgments given for each face should not be influenced by the perceptual outcome in the first part of the trial. Note that the term “long-staying face” rather than “adaptor” was used when explaining the task, in this and the following experiments. This phrasing was chosen to avoid biasing participants with expectations about the effects being studied.

There were 60 test trials in each condition, split into two QUEST staircases of 30 trials each, one initially increasing and the other decreasing. Each staircase was initiated with an extreme facial expression, either the extremely happy morphed face (0) or the extremely sad morphed face (99), to counteract possible response biases from the starting direction of the staircase. Each staircase was randomly interleaved on a trial-by-trial basis. At the end of each block, the point of subjective equality (PSE, i.e., the stimulus for which the participant was equally likely to judge it as happy or sad 50% of the time) for each staircase was calculated using a Bayesian adaptive algorithm QUEST (with the function QuestMean; Watson & Pelli, 1983). The PSEs from the two staircases were then averaged to derive a single estimate for each condition, separately for the *happy* and *sad* conditions. Participants underwent one self-paced, untimed break in the middle of each block. The experiment started with an initial 60 s exposure to the neutral face, and participants were asked to autosuggest, as described above. This long adaptation period was repeated after the break in the middle of the block. At the end of all experiments, participants were debriefed on the purpose of maintaining a continuous focus on the adapting stimuli.

Before and after the experiment, participants rated their mood on a visual analog scale (VAS), with 0 corresponding to feeling sad and 100 corresponding to feeling happy. Evidence suggests that one's own moods may interact with emotion perception in others (Sel et al., 2015). At the end of the experiment, participants filled out the following questionnaires: 1) The Spontaneous Use of Imagery Scale (SUIS; Kosslyn et al., 1998, 12-60 points) to assess the spontaneous use of visual imagery in everyday life, 2) The Short Suggestibility Scale (SSS, 21-105 points), a condensed version of Multidimensional Iowa Suggestibility Scale (MISS; Kotov et al., 2004) to assess participants' overall compliance with suggestions, and 3) The Vividness of Visual Imagery Questionnaire 2 (VVIQ2, 16-80 points; Marks, 1973) with eyes open and closed, to evaluate vividness of participants' visual images. In addition, participants answered several open questions to gain insight into how participants performed autosuggestion. The questions, responses, questionnaire ratings, and qualitative results are available via the following link: https://osf.io/wk9xq/?view_only=aabe0f707ce243e180c1ed34a8d0bfc7.

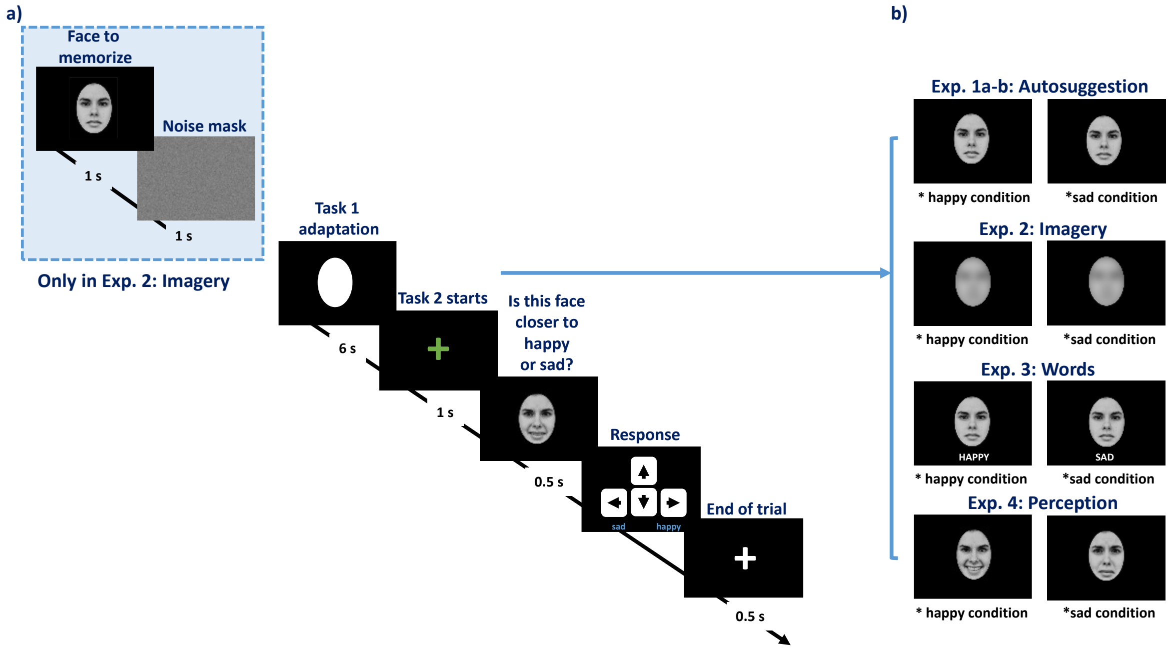

Figure 10. Trial sequence and adapting stimuli used in all experiments. a) The experimental design was consistent across experiments encompassing two tasks in each trial: task 1 - exposure to the adaptor and task 2 - judgment of emotions in test faces. Note: in Experiment 2 (imagery), each trial started with the presentation of a neutral face for 1 s to remind participants of the identity of the person they were asked to keep in their minds, followed by a mask covering the full screen (see the content surrounded by dotted blue line). Each trial continued (or started for the rest of the experiments) with the display of an adapting stimulus for 6 s (see **B** for the specific adapting stimuli). After the green cross appeared on the screen to signal the end of the first task and the start of the second task, a test stimulus appeared. Participants were asked to judge whether the test faces

looked closer to the emotion happy or closer to the emotion sad. The face stimuli to judge were morphed faces of happy and sad expressions of the same female identity. The selection of test stimuli was determined by a Bayesian adaptive algorithm QUEST (Watson and Pelli, 1983), based on the history of previous responses. After a response was made, a white fixation appeared, to signal the end of the trial. **b)** During the adaptation phase in Experiment 1a and 1b (autosuggestion), participants were exposed to a neutral face, and their task was to reiterate thoughts stating that the person they were observing looked very happy or very sad. To strengthen the effects of autosuggestion, they were instructed to perceive the noisy pixels on the image as contributing to the perception of the person's happiness or sadness (Experiment 1a). In Experiment 1b this instruction was omitted and instead, participants were asked to avoid using imagery to their best abilities. In Experiment 2 (imagery), an oval shape with a blurred contour of the face was presented on the screen, and participants were asked to imagine the earlier seen neutral female face as happy or sad. In Experiment 3 (words), participants looked at the adapting stimuli containing the same neutral faces as in Experiment 1, however this time the word: "HAPPY" or "SAD" was presented beneath the face, corresponding to each experimental condition. In Experiment 4 (perception of physical stimuli), participants viewed an extremely happy or sad face, depending on the experimental condition. **Figure adapted from:** Myga et al., *bioRxiv*, 2025, p. 9

Exclusion Criteria

Participants who were exposed to extreme test stimuli – either the happy (0) or sad (99) morphed faces – for more than 50% of trials in a staircase were excluded, as this pattern indicated a strong response bias that compromised threshold estimation in the QUEST adaptive psychometric procedure. Five participants were excluded on these bases. This exclusion criterion also addressed additional issues in some of these participants, including thresholds exceeding the 0-99 range or significant discrepancies between thresholds obtained across the two staircases within the same condition. Among the included participants, all experienced extreme trials (either the happiest or saddest face) in 43% or fewer of their trials, with most encountering extreme stimuli only on the first trial.

Analyses

Points of subjective equality (PSEs) were calculated using a Bayesian adaptive algorithm QUEST (Watson & Pelli, 1983), which estimated the percentage of morph at which participants were equally likely to judge the test face as happy or as sad. We obtained two PSEs per condition, which were averaged, resulting in one PSE value for each participant and condition.

We used a paired sample t-test to compare the two PSE values between the *happy* and *sad autosuggestion* conditions, with the significance level set to .05, and reported Cohen's d_z as a measure of effect size. When the assumption of normality was violated (Experiments 1a-b and 2), we conducted the non-parametric Wilcoxon signed-rank test and reported the results of both tests. As the same conclusions were reached with both tests, we draw conclusions based on t-tests and Cohen's d_z in all cases for consistency and comparability of the results.

6.2.2 Results

PSEs

We observed a significant difference between the PSEs in the *happy* versus *sad* condition (see **Figure 11: Autosuggestion 1a**). More precisely, in the *happy* condition, the PSE was higher (i.e., a facial morph closer to sadness, M = 48.75, SD = 16.28), meaning participants required a facial morph closer to a sad expression before identifying it as sad. In contrast, in the *sad* condition, the PSE was lower (M

= 37.61, SD = 16.07), indicating that participants judged faces as sad even when they displayed more pronounced happy features. This shift in PSE in the direction of the adaptor demonstrates an assimilative aftereffect. The effect was statistically significant, t(17) = 3.144, p = .006, d_z = 0.741, with a medium to large effect size. We report the Wilcoxon signed-rank test for completeness, as the assumption of normality was violated: z = 2.504, p = .01, r = -.673.

For completeness, we repeated the analysis including the five outliers but excluded only the affected staircase data. Although this approach yields less robust data due to fewer trials and the likelihood that participants with strong biases in one staircase may not provide accurate estimations, the results remained significant: PSE happy M = 47.57 (SD = 17.73); PSE sad M = 39.62 (SD = 16.46); t(22) = 2.285, p = .032, d_z = -.477.

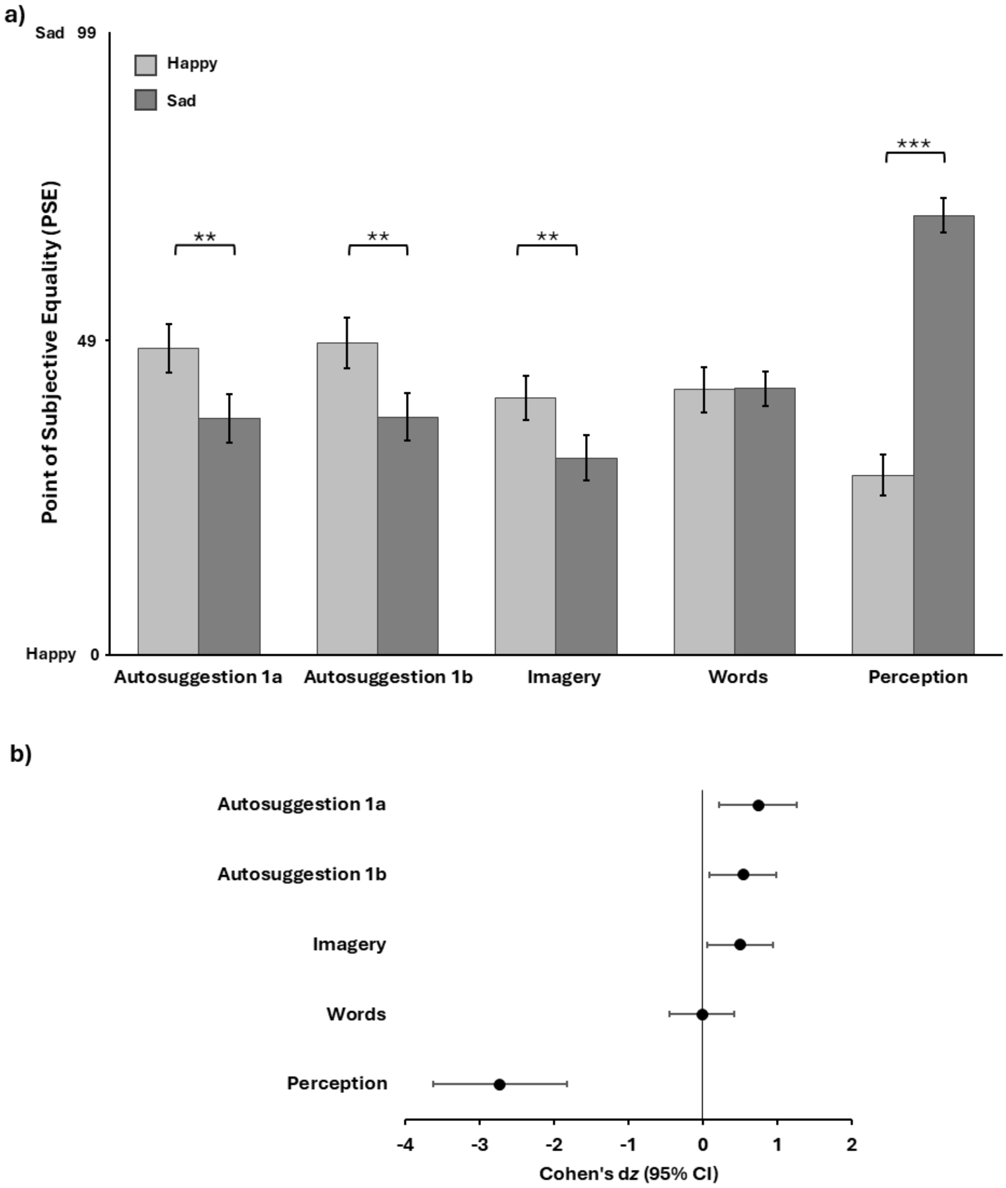

Figure 11. Overview of experimental results. a) Comparison between PSE in *happy* and *sad* conditions in all experiments. Both experiments on autosuggestion (Experiment 1a and 1b) as well

as imagery produced assimilative aftereffects: the PSE in the *happy* condition was significantly higher than the PSE in the *sad* condition, as indicated by the paired sample t-test. After prolonged autosuggestion or imagery of a neutral face as "happy" or "sad", they perceived a greater number of test faces in the direction of the autosuggested or imagined emotion. In an experiment where adapting neutral faces were paired with emotion describing the words: "HAPPY" or "SAD", no PSE difference was observed between the two conditions. Conversely, in the perceptual experiment, using extremely happy and sad faces as adaptors, contrastive aftereffects were observed: the mean PSE in the *happy* condition was significantly lower than in the *sad* condition, indicating test faces were perceived in the opposite direction to the adapting emotion. Error bars represent Standard Error. Asterisks indicate significance level at p values: ** for $p \leq .01$ and *** for $p \leq .001$. **b) Effect size by experiments (Cohen's d_z).** The solid vertical line represents no effect of experimental manipulation. Each circle represents the point estimate of the effect size for the study corresponding to the label on the left. The line on the left and the right of the circle represent the lower and higher CIs for the effect size. Points to the left of the line represent contrastive adaptation aftereffects and points to the right of the line indicate assimilative aftereffects. **Figure source:** Myga et al., *bioRxiv*, 2025, p. 11

Mood, suggestibility and imagery scores

Participants' mood ratings at the start (M = 70.79, SD = 25.68) and the end (M = 64.83, SD = 26.33) of the experiment showed no significant difference, $t(17) = 1.070$, $p = .300$, $d_z = -.252$. Their mean suggestibility score (M = 49.94, SD = 9.91; Kotov et al., 2004), spontaneous imagery use (M = 41.17, SD = 7.49; Nelis et al., 2014, Sample 1), and vividness of imagery (combined eyes open/closed M = 67.08, SD = 10.53) aligned with prior studies (Azañón et al., 2024; Tabi et al., 2022).

Task strategies overview from follow-up questionnaires

Participants were instructed to repeat autosuggestive sentences while interpreting ambiguous visual elements, particularly around the mouth and eyes, as indicating specific emotional expressions. Self-reports indicate that participants primarily focused on facial analysis for autosuggesting emotions rather than verbal suggestion, with 83% reporting imagery use overall. 83% of the participants reported changing their own expressions and mood shifts during the experiment, in alignment with the autosuggested emotion. A minority (11%) superimposed autosuggested emotions onto the screen, while 17% relied on verbal suggestions with complementary techniques. Please note that due to variability in responses and to maintain conciseness, only the most frequent answers are reported in this and the following self-report sections. Percentages may not total 100%. For a comprehensive overview of the self-reports and questions, please refer to the Supplementary Material (**Annex 2a** or https://osf.io/wk9xq/?view_only=aabe0f707ce243e180c1ed34a8d0bfc7).

6.3 Experiment 1b: autosuggestion – modified instructions

The results of the first experiment indicated a significant reliance on imagery and personal emotional engagement during the autosuggestion process with minimal use of repetitive verbal phrases (e.g., "This person is happy", "This person is sad"). This made it difficult to assess whether the observed effects could also emerge when using suggestion in the form of intentional thought repetition. To address this, we conducted a second experiment with stricter instructions to further discourage participants from using imagery during the autosuggestion task.

6.3.1 Materials and methods

Participants

Altogether 23 participants were tested individually or in groups, each seated in separate cabins. Data from one outlier were excluded based on the same exclusion criteria as for Experiment 1a, leaving 22 participants for analyses (12 females, M age = 27.82, SD = 3.78). One participant was left-handed, one was ambidextrous, and the rest of the sample was right-handed (mean = 82.25, SD = 43.58, range: -100 – 100).

Stimuli

Stimuli were the same as those used in Experiment 1b.

Experimental procedure

In this adapted version of Experiment 1a, we emphasized to participants in the instructions that they should avoid imagery. Specifically, we removed guidance to interpret ambiguous visual elements – particularly around the mouth and eyes – as indicative of specific emotional expressions. For instance, in the *happy* condition, we eliminated instructions like "Notice that the mouth corners are pointing upwards" or "Wrinkles around the eyes indicate happiness" while mentally repeating "She is happy", as, based on the results of Experiment 1a, we concluded that such cues encourage participants to rely more on imagery. Additionally, we included more targeted questions about the autosuggestion process and collected mood ratings before and after each condition to account for possible mood fluctuations following autosuggestion (see https://osf.io/wk9xq/?view_only=aabe0f707ce243e180c1ed34a8d0bfc7 for the detailed questions). In addition, a controlled 5-minute break between the two conditions was introduced, replacing the participant-controlled break. Furthermore, we collected mood ratings before starting the experiment, after the first condition, before the second condition, and at the end of the experiment. Finally, to reduce testing time, we administered the VVIQ2 questionnaire only with eyes open, as participants would need their eyes open to track dynamic changes on the screen if they were to use imagery.

6.3.2 Results

PSEs

The results of Experiment 1b closely parallel those of Experiment 1a, despite the slight modification of instructions, which emphasized the avoidance of visual imagery. The PSE in the *happy* condition (M = 49.58, SD = 18.85) was significantly higher than the PSE in the *sad* condition with a medium effect size (M = 37.84, SD= 17.48), t(21) = 2.504, p = .021, d_z = -.534 (see **Figure 11: Autosuggestion 1b**). We report the Wilcoxon signed-rank test for completeness, as the assumption of normality was violated: z = 2.613, p = .007, r = -.636.

Mood, suggestibility and imagery scores

Participants' mood ratings before (M = 65.04, SD = 22.34) and after the experiment (M = 61.55, SD = 20.72) did not differ, z = .087, p = .945, r = .022. The mood rating before starting the *happy* condition (M = 65.83, SD = 22.50) did not significantly differ from the mood rating after completing this condition (M = 64.77, SD = 17.97), z = 1.185, p = .248, r = -.239. Additionally, the mood before starting the sad condition (M = 63.392, SD = 21.08) was lower than the mood after starting the *sad* condition (M = 54.45, SD = 23.08), but this difference did not reach statistical significance, z = 1.860, p = .065, r = .463. Participants showed average suggestibility (M = 51.27, SD = 12.41; Kotov et al., 2004), spontaneous imagery use (M = 39.73, SD = 8.55; Nelis et al., 2014, Sample 1), and vividness of imagery (M = 58.73, SD = 10.11; Azañón et al., 2024, Tabi et al., 2022).

Task strategies overview from follow-up questionnaires

The majority of participants (86%) repeated autosuggestive sentences describing intended emotions. Mental imagery was used by 59%, and 36% reported superimposing imagined expressions in at least one condition. Participants moderately changed their facial expressions (M = 2.77, SD = 1.45; scale 1–5) and leaned slightly toward verbal suggestions over imagery (M = 2.55, SD = 1.22; scale 1 = verbal, 5 = visual). Perceived autosuggestion effectiveness averaged as "moderately" for both conditions: M happy = 3.1 (SD = 1.07), M sad = 3.6 (SD = .99). Detailed responses are in Supplementary Material (**Annex 2b** or https://osf.io/wk9xq/?view_only=aabe0f707ce243e180c1ed34a8d0bfc7).

6.4 Experiment 2: mental imagery

In Experiment 2, participants viewed a neutral face and, after it disappeared, they were instructed to imagine the person as happy or sad (see **Figure 10**). This approach differs from the autosuggestion experiments in the sense that rather than attempting *to modify* the perceived expression of a physical stimulus through suggestion, participants instead focused on *creating a new emotional image* in their minds.

Using a previously seen object as a basis for imagery is a common approach and aligns with Kosslyn's (1995) mental imagery framework which involves such abilities as: 1) Image inspection, 2) Image generation in their minds, 3) Mental image transformation, where they alter the memory; and 4) Image retention, where they maintain the altered image until the test trial. We expected that the prolonged imagery of a happy or sad face would influence subsequent emotion perception. However, the direction of this effect remained uncertain due to conflicting findings in prior research (D'Ascenzo et al., 2014; DeBruine et al., 2010; Korolkova, 2018; Palumbo et al., 2017; Zamuner et al., 2017).

6.4.1 Materials and methods

Participants

Altogether 24 participants were tested individually. One participant stopped midway, and one participant was excluded following the same exclusion criteria as in the previous experiments. 22 participants formed the final sample (10 females, M age = 26.77, SD = 5.34). 18 participants were right-handed, two were left-handed and two were ambidextrous (mean 67.18, range: -100 – 100).

Stimuli

The same stimuli from Experiments 1a-b were used in Experiment 2, with the addition of a blurred oval image presented during the adaptation phase, after the disappearance of the neutral face. The blurred image was used to improve the generation and vividness of the imagined adaptor face in the inner eye, as suggested by D'Ascenzo and colleagues (2014). The blur was superimposed on the neutral emotion female face using the blurring tool available in GIMP version 2.10.32 and had the same size and location as the previously seen neutral face and the test faces.

Experimental procedure and analyses

The experimental procedure was similar to Experiment 1a-b. The main difference was that instead of asking people to reiterate a thought internally that would influence their emotion perception, participants were asked to imagine the previously seen neutral faces as happy or sad, while looking at a blurred outline of a neutral face (see **Figure 10**).

At the start of each condition and after each break, participants viewed the neutral face for 5 s. They were asked to memorize this face, to later imagine it as happy or sad. Then, a noise mask covering the full screen was displayed for 1 s to minimize the creation of any after-images. This noise mask was created in Matlab using the imnoise function with a "salt and pepper" noise pattern, and noise density set to 1. This was followed by the presentation of the blurred face for 60 s. During this time, participants were required to imagine the previously seen face as very happy or very sad. Each trial followed a similar structure with shorter durations: neutral face for 1 s, noise mask for 1 s, and blurred face for 6 s as the adaptor. In the second task, as in Experiments 1a-b, participants viewed a test face for 0.5 s and indicated whether it appeared closer to happy or sad. A white cross marked the end of each trial for 0.5 s. There were 60 trials per condition and 120 trials in the whole experiment.

Before the start of the experiment, participants were shown a demonstration of the imagery procedure, as well as the trial structure, with only 10 trials per condition. Just like in Experiment 1, it was stressed to participants that they should evaluate the test faces independently from the outcomes in the imagery phase. Participants filled out the same questionnaires as in Experiment 1a, and open-ended questions where the word "autosuggestion" was replaced with the word "imagery". Analyses were identical to Experiment 1.

6.4.2 Results

PSEs

The results aligned closely to those of Experiments 1a and 1b (see **Figure 11: Imagery**). The PSE in the *happy* condition (M = 40.93; SD = 16.39) was significantly larger than in the *sad* condition (M = 31.35; SD = 17.16), t(21) = 2.334, p = .030, d_z = -.498, suggesting an assimilative aftereffect. Specifically, in the *imagine sad* condition, participants identified faces with about 30% sad content as equally happy or sad. In contrast, in the *imagine happy* condition the amount of sad content needed to be larger to categorize that face as equally happy or sad, indicating a bias toward categorizing faces as happier, even when sadder features were more prominent than in the *imagine sad* condition. We report the Wilcoxon signed-rank test for completeness, as the assumption of normality was violated: z = 2.354, p = .017, r = -.573.

Mood, suggestibility and imagery scores

Participants' mood ratings did not differ before (M = 69.86; SD = 22.40) and after (M = 61.29; SD = 20.24) the experiment took place, t(21) = 1.567, p = .132 , d_z = -.334. Participants displayed average suggestibility levels (M = 47.59, SD = 11.35), spontaneous use of imagery (M = 39.91, SD = 7.10), and imagery (combined open/close eyes M = 63.21, SD = 9.12, based on: Azañón et al., 2024, Tabi et al., 2022).

Task strategies overview from follow-up questionnaires

In brief, a variety of strategies were employed to imagine happy and sad faces. For imagining happy faces, about 23% of participants recalled personal or others' experiences of happiness, while 41% did not disclose their specific process. When imagining sad faces, approximately 27% referred to personal or others' experiences, and 32% described only the perceptual outcome. In terms of imagery techniques, 36% placed the imagined person in a specific situation, and 23% superimposed the imagined image on the blurred outline presented on the screen. 59% of participants reported changing their own mood to match the imagined emotion. For a detailed overview of the self-report, refer to the Supplementary Material (**Annex 2c** or https://osf.io/wk9xq/?view_only=aabe0f707ce243e180c1ed34a8d0bfc7**)**.

6.5 Experiment 3: emotional words

The preceding results suggest that autosuggestion and mental imagery influence the perceived emotion of observed faces in the direction of the autosuggested or imagined emotion. Experiment 3 explored whether this effect could partly result from a response bias (by reporting for instance more frequent "happy" responses in the *happy* condition). To examine this, we added the words "HAPPY" or "SAD" under the neutral face as an adapting stimulus, without instructing participants to evoke any specific emotion. If judgments were biased by these words, similar aftereffects to those in Experiments 1a-b and 2 would be expected. If not, it would suggest that response bias is not the primary factor driving the results observed previously.

6.5.1 Materials and methods

Participants

Altogether 21 participants took part in the experiment (10 females, M age = 26.14, SD = 3.44). There were no outliers based on the imposed criteria. All participants were right-handed (M = 91.78; range: 57.10 – 100).

Stimuli

Adapting stimuli were neutral faces as in Experiments 1a-b, however in Experiment 3, the following written English words were presented below the face: "HAPPY" or "SAD" (see **Figure 10**). The words were presented centrally, 2.15 degrees of visual angle below the face in capital letters (Calibri 44), and with a letter height of 1.13 degrees of visual angle. Note, that the size of adapting and test faces were identical across experiments, and that all communication between the experimenter and participants was in English).

Experimental procedure and analyses

The experimental procedure and analyses were identical to Experiment 1a, with the only exception that the adapting stimulus contained the written word: "HAPPY" or "SAD". To ensure sustained attention to the neutral face, despite potential boredom or fatigue, participants were informed they would need to answer detailed questions about that face at the end of the experiment. The emotion words written under the adaptors were never mentioned to the participants. Before and after the experiment, participants were presented with the mood scale, and at the end of the experiment, participants responded to open-ended questions about the experiment (see questions and responses in **Annex 2d** or via the link on https://osf.io/wk9xq/?view_only=aabe0f707ce243e180c1ed34a8d0bfc7).

6.5.2 Results

PSEs

The mean PSE in the *happy* condition (M = 42.19; SD = 16.43) did not differ significantly from the mean PSE in the *sad* condition (M = 42.39; SD = 12.62), t(20) = -.079, p = .938, d_z = -.017 (see **Figure 11a-b: Words**). This suggests that the emotional words alone did not influence participants' judgments.

Mood scores and self-reports

Participants' mean mood ratings before (M = 63.11; SD = 26.82) and after (M = 66.85; SD = 22.63) the experiment did not differ significantly, t(20) = .971, p = .343, d_z = .212.

Task strategies overview from follow-up questionnaires

Approximately 86% of participants reported focusing primarily on the eyes and other facial features. When asked about their thoughts during the task, about 62% analyzed the emotional expression of the face in reference to the words, with 29% of them noting a discrepancy between the observed face and the emotion word. 90% of participants reported paying attention to the words, although some did so only partially or initially. The influence of these words on participants' answers was mixed, with 52% reporting being affected by the words and 38% claiming their answers remained unaffected. When asked to guess the experiment's purpose, 52% expected the words under the adaptors to influence their answers. Finally, 57% correctly answered the question that they should judge the test faces (those shown for a shorter period), while 43% made comments unrelated to this question. The exact report of the answers can be found in the Supplementary Material (**Annex 2d** or https://osf.io/wk9xq/?view_only=aabe0f707ce243e180c1ed34a8d0bfc7**)**.

6.6 Experiment 4: perception

Contrastive aftereffects are typically observed when participants are exposed to physical stimuli depicting extreme emotions; viewing a happy face, for example, generally makes subsequent faces appear sadder (e.g., D'Ascenzo et al., 2014; DeBruine et al., 2010). However, in our previous experiments, participants were not presented with physical extremes but rather engaged in mentally constructed extremes through suggestion (Experiments 1a-b) or imagery (Experiment 2). As a result, we observed assimilative rather than contrastive aftereffects. To ensure our paradigm's validity and to confirm that it can elicit both types of aftereffects, we conducted Experiment 4, adapting participants to actual extreme expressions and testing the same stimuli as in our previous experiments.

6.6.1 Materials and methods

Participants

Altogether 23 participants took part in Experiment 4 (11 females, M age = 24.91, SD = 3.49). There were no outliers based on the imposed criteria. 22 participants were right-handed and one participant was left-handed (M = 86.52; range: -100 – 100). Participants were tested individually or in groups, each seated in separate cabins.

Stimuli

Adapting stimuli consisted of the happy (AF29HAS) and sad (AF29SAS) expressions used in the previous experiments as extremes to construct the continuum of test stimuli (see **Figure 10**).

Experimental procedure

The methods and analyses, including the practice session, were identical to Experiment 3, with the only difference being that the adapting stimuli were replaced by an actual happy or sad face. Participants were instructed to maintain their gaze on the adaptors. As in Experiment 3, to motivate participants to continuously look at adapting stimuli, they were told that at the end of the experiment, they would respond to questions asking details about them.

6.6.2 Results

PSEs

There was a significant difference between PSEs across the two conditions (see **Figure 11: Perception**). The mean PSE in the *happy* condition (M = 28.62; SD = 15.54) was significantly lower than the mean PSE in the *sad* condition (M = 69.90; SD = 13.11), $t(20) = -13.122$, $p < .001$, $d_z = -2.736$, with a very large effect size. These results reflect contrastive aftereffects, namely adaptation to a happy emotion, biased the perception of test faces towards sadder emotion, and the opposite was true after adaptation to a sad face.

Mood scores

Participants started and finished the experiment with mood ratings of M = 79.27 (SD = 18.35), and M = 74.82 (SD = 18.52), these ratings did not differ significantly from each other, $z = 1.120$, $p = .270$, $r = .273$.

Task strategies overview from follow-up questionnaires

Across all 23 participants, everyone consistently reported that they looked at the face that stayed on the screen for a “longer period of time” (100%). Regarding their thoughts while observing the faces, 61% analyzed the emotional content of the faces, while smaller percentages focused on other aspects, such as remembering features (9%), or had experiences like confusion or frustration (4%). When judging happy or sad faces, 65% of participants reported judging the test faces, 13% gave judgments about the adaptors, and 22% gave answers unrelated to the question. In terms of understanding the experimental manipulation, 17% showed awareness of contrastive adaptation effects, 9% made guesses about assimilative effects, 30% believed the adaptor influenced their judgments but did not specify how, and 26% seemed unclear on the experimental manipulation. The summary of the responses is available in **Annex 2e**, and the exact responses can be accessed via link on: https://osf.io/wk9xq/?view_only=aabe0f707ce243e180c1ed34a8d0bfc7.

6.7 Discussion

This study investigates two cognitive strategies that influence facial emotion perception, namely autosuggestion and mental imagery. In an adaptation paradigm, participants were asked to use autosuggestion to *perceive* the expression of a neutral female face as happier or sadder than it actually is (Experiments 1a-b) or to *imagine* the previously seen neutral face as being happy or sad (Experiment 2). In all three experiments, participants judged test faces as happier or sadder, respectively, both when performing autosuggestion and when imagining the respective emotion. Critically, we found no effects of adaptation to facial neutral expressions that were accompanied by emotional words (Experiment 3), suggesting, that the effects observed in the first two experiments were not an expression of response bias, but the results of a cognitive process centered on autosuggestion and mental imagery. Finally, we observed classical, contrastive aftereffects when a happy or a sad face was used as an adaptor (Experiment 4), further supporting the notion that our paradigm successfully replicated established perceptual adaptation aftereffects (D’Ascenzo et al., 2014; DeBruine et al., 2010; Ellamil et al., 2008; Kaping et al., 2002). Together, our experiments show that both autosuggestion and mental imagery can be used to modulate emotion perception in a social context.

Experiment 1a showed that autosuggestion modulates emotion perception in such a way, that the emotions in test faces resemble more the adapting faces. More precisely, the same face was perceived as happy when adapting stimuli were autosuggested to look happy, or sad when autosuggesting sad emotion perception. However, as most participants of Experiment 1a reported creating visual images to support their autosuggestion, despite instructions to avoid imagery, the study could not completely distinguish between the processes of imagery and autosuggestion. In Experiment 1b, therefore, revised instructions emphasized verbal suggestion, reducing reliance on imagery. This led indeed to an increased reliance on verbal suggestions and a decrease in imagery use. However, participants still often combined verbal strategies with mental imagery and other techniques. The tendency to use imagery in the autosuggestion group highlights several points: participants may conflate autosuggestion with imagery despite understanding the distinction; they might simply lack the skills to effectively use autosuggestion in the form of intentional thought repetition without associated imagery; or individuals with strong imagery abilities may find it difficult to avoid using them, naturally combining both techniques to enhance outcomes. Autosuggestion appears to be a flexible process that engages multiple cognitive strategies, and the extent to which participants rely on imagery or verbal repetition may depend significantly on task instructions and individual tendencies. Future research could explore autosuggestion in individuals who are unable to create mental images (aphantasics, e.g., Monzel et al., 2023; Reeder et al., 2024) to help distinguish pure thought repetition, from imagery-supported autosuggestion.

Our findings suggest that biases in perceiving facial expressions can emerge both through imagery alone (Zamuner et al., 2017) and during autosuggestion. Despite the strong interplay between these processes, the tasks likely differ in their cognitive demands and underlying intentions. In the *imagery only* task, participants create an emotional face in the absence of any visible stimulus. In contrast, the *autosuggestion* task involves actively altering the perceived emotion of a physically present stimulus by reinterpreting a neutral face as happy or sad. This distinction holds significant implications for daily experiences, suggesting the possibility of intentionally altering one's perception of another's facial expression, especially in face-to-face interactions.

Experiments 1a-b and 2 demonstrated assimilative aftereffects, whereas Experiment 4, which used physical extreme stimuli, resulted in contrastive aftereffects. One possible interpretation of these differing effects aligns with the findings by Korolkova (2018), who noted a distinction in the direction of aftereffects based on the nature of the adapting stimuli. Specifically, the study found contrastive aftereffects with static images of emotional faces, whereas assimilative aftereffects were observed with stimuli that dynamically alternated between expressions, such as disgust and happiness. Our findings parallel this distinction. In Experiments 1a-b and 2, participants reported placing the imagined or autosuggested emotion in a situational context. In the imagery experiment, they generated mental representations of scenes rather than holding one static image of a face in the mind's eye. Similarly, participants' feedback indicated that when autosuggesting a specific emotion, the image they looked at on the screen, fluctuated in perceived intensity of the suggested emotion, aligning with the dynamic qualities associated with assimilative effects proposed by Korolkova (2018).

The assimilative effects observed may also reflect priming on participants' judgments. For example, Carroll and Young (2005) demonstrated that emotional priming, using words or emotion-related stimuli presented for only 0.5 s immediately before the test stimuli, led to faster and more accurate emotion recognition when the primes matched the target facial expressions. In a complementary approach, Fischer and Whitney (2014) proposed that perception is dependent on both prior and current perceptual information, a phenomenon termed serial dependence, which fosters continuity in perception despite environmental noise. To illustrate this point, Liberman and colleagues (2014) showed that participants' perception of facial identity was biased towards identities seen up to several seconds before, independent of their previous responses. Notably, the 7-second time difference between viewing a previous face and a current target face, as reported by Liberman and colleagues corresponds to the delay between the onset of the imagined/autosuggested face and the presentation time of the test face in our paradigm (see **Figure 10a**), which may suggest a tendency toward perceptual continuity in our findings.

Contrastive aftereffects are commonly observed with perceptual stimuli, as demonstrated in Experiment 4, where participants are typically exposed to adaptors representing an extreme end of the stimulus spectrum, especially in the context of high-level adaptation aftereffects (Ambroziak et al., 2023; Clifford & Rhodes, 2005; Myga et al., 2024a; Pell & Richards, 2011). Although one might speculate that the milder, mentally generated adaptors in Experiments 1a-b and 2 could account for the directional differences observed, this is unlikely, as the intensity of adapting stimuli generally influences aftereffect strength rather than direction (Burton et al., 2013; Calder et al., 2008; Hong & Yoon, 2017; Lawson et al., 2009; Rhodes et al., 2017). It is also noteworthy that the effect sizes in the autosuggestion and imagery experiments were moderate, but these outcomes contrast sharply with the large effect size seen in Experiment 4, where every participant exhibited numerically the effect. In contrast, only 14 of 18, 16 of 22, and 17 of 22 participants showed the predicted numerical effect in the autosuggestion and imagery experiments, underscoring the greater variability in response to mentally generated adaptors compared to the consistent, robust effects elicited by physical adaptors.

While multiple interpretations for the aftereffects are plausible, the primary aim of this study was not to differentiate whether the observed effects stem from adaptation, priming, or serial dependence, but rather to assess our approach's efficacy in influencing subsequent perceptions and determining the effect's direction. To address potential response bias (Nichols & Maner, 2008; Orne, 1962), we conducted Experiment 3, exposing participants to neutral faces with "HAPPY" or "SAD" labels. Contrary to demand bias expectations, participants showed no consistent bias based on the labels. Although many participants noticed the words and believed they should and did influence their judgments, our findings indicate that the deliberate intent to perceive specific emotions, as in Experiments 1a-b and 2, is necessary for significant shifts in emotion perception. Experiment 3 thus supports the idea that the effects observed in the earlier experiments extend beyond simple response bias and highlight the role of active cognitive engagement in altering facial emotion perception.

As an exploratory measure, we asked participants to rate their mood as well as to indicate more details on how they evoked imagery or autosuggested states in themselves. Evidence suggests that emotion processing may be affected by one's mood (Sel et al., 2015). We observed a significant mood drop after autosuggesting sad emotions and a mood increase after autosuggesting happy emotions in participants in Experiment 1b. Note that this within-condition comparison was only possible in Experiment 1b, as other experiments included mood ratings solely at the beginning and end. Moreover, in both the autosuggestion and imagery experiments, the majority of participants reported modifying their facial expressions or emotional states to facilitate the generation of autosuggestive and mental images outcomes. This finding aligns with research demonstrating that modulating facial mimicry – either by inhibiting or enhancing it – can influence the recognition of emotional facial expressions (Rychlowska et al., 2014; Sel et al., 2015).

Our results might be an early indicator that exposure to certain emotional stimuli could potentially be exploited as a tool to bias emotion perception in the longer term. However, while the endurance of adaptation aftereffects in various aspects of face perception has been extensively studied, including those related to identity (Carbon et al., 2007; Carbon & Ditye, 2011), investigations into long-lasting adaptation effects in emotion perception seem lacking. Carbon and Ditye (2011) conducted a series of experiments where participants exhibited sustained adaptation aftereffects, lasting up to a week, following exposure to distorted images of familiar faces. These effects not only persisted over time but also generalized across different images of the same individual and even extended to other identities. Along these lines, it has been proposed that body shape misperception, as in eating disorders, might be an example of long-term adaptation aftereffects caused by recalibration of the perceptual system to the exposure to a constant media extreme of "ideal", very thin, bodies (Brooks et al., 2020). In that regard, exposure to bodies of larger size might serve as a therapeutic intervention in patients with eating disorders (Challinor et al., 2017; Porras-Garcia et al., 2020).

In light of these findings, our study might similarly recalibrate emotional perception, potentially biasing the interpretation of others' facial expressions. Future research should explore the durability of these effects in emotion perception and assess whether prolonged exposure to specific emotional stimuli could lead to more enduring perceptual biases. Nonetheless, several limitations of this study need to be considered. First, we used the same facial identity throughout the study, limiting the generalizability of our findings, and the sample primarily consisted of individuals from or residing in Europe, which may restrict broader applicability. Additionally, while our effect sizes were substantial, they were not as large as those observed with physical stimuli, and the effects were not uniform across all participants, suggesting limitations in the potential practical application of autosuggestion and imagery techniques. Furthermore, despite efforts to control for response bias, it remains possible that such biases contribute to the observed assimilative aftereffects, a limitation that is present in all studies showing assimilative aftereffects. Another important consideration is whether our procedures genuinely bias perception or simply influence the interpretation of emotional stimuli. Additionally, we cannot definitively conclude whether autosuggestion and mental imagery represent distinct tasks, as the first three experiments might have tapped into the same underlying mechanism, only differing in the presence or absence of the neutral physical stimulus. Although we believe that participants approached each task with different intentions, and therefore engaged in different cognitive processes, we cannot be certain of this distinction.

Finally, we included various self-report questionnaires to capture individual differences in task performance. While our analysis was broad, focusing on general trends rather than on individual differences, the self-reports offered important insights into how participants approached the tasks. For instance, many participants in Experiment 1a omitted the verbal repetition component of autosuggestion, focusing instead on visualizing the suggested emotion. Similarly, in the mental imagery experiment, participants often did not evoke the identity of the neutral face but engaged in other forms of visualization based on their emotional targets. These findings underscore the importance of understanding participants' interpretations of task instructions and their strategies for performing cognitive tasks. Indeed, overlooking this information, as is often the case in cognitive neuroscience, prevents a full understanding of whether the cognitive process intended by the study design is indeed the one participants engage in.

In conclusion, our study provides evidence that exposure to emotional stimuli through autosuggestion or imagery can lead to a consistent bias in perceiving and interpreting facial emotions in others. These findings highlight the potential for training and deliberate application of self-directed interventions, such as imaginative and autosuggestive techniques, to shape the perception of emotional expression.

Data availability

All data and analysis scripts, have been made publicly available via OSF and can be accessed via the following link: https://osf.io/wk9xq/?view_only=aabe0f707ce243e180c1ed34a8d0bfc7.

Chapter 7

General discussion

The concept of autosuggestion, introduced by Émile Coué more than a century ago, remains a central idea in self-help and personal development literature. While many contemporary authors highlight the role of thought in shaping our reality (Clark, 2024; Fuller, 2010; Hay, 2004; Leaf, 2013; Peer, 2009), scientific research on autosuggestion has been scarce. This thesis explores the influence of autosuggestion on various aspects of human cognition and perception. Through a series of experiments, I aimed to explore reliably the potential effects of autosuggestion across tactile perception, body representations, and emotion perception. This general discussion summarizes our findings and discusses possible underlying mechanisms, cognitive processes potentially involved in autosuggestion, and methodological considerations for this early research stage. As one of the first attempts to scientifically examine autosuggestion in these contexts, our research opens up new avenues for future investigations and highlights the potential implications of this understudied phenomenon, as the challenges associated with the investigation of autosuggestion.

7.1 Various effects of autosuggestion – overview of the results

In the initial stage of our research, we focused on the influence of autosuggestion on tactile modality. We were motivated by the practical side of the experimental context and its far-reaching implications. Specifically, sensorimotor systems offer a well-defined framework for experimental work. Tactile sensations can be precisely controlled and measured using standardized equipment, allowing accurate comparison between conditions.

In Study 1 (Chapter 3), we conducted a series of experiments to examine the effects of autosuggestion on tactile intensity perception. In our paradigm, participants were instructed to focus on the intensity of tactile stimuli, using autosuggestion to modulate their intensity. However, instead of directly asking participants to report the effects of autosuggestion on perceived intensity, we made use of the Békésy effect, a well-established relationship between perceived frequency and intensity. By increasing the intensity of vibrotactile stimuli while maintaining constant frequency, we could indirectly measure autosuggestion's effect through changes in perceived frequency. Because individuals are unaware of this coupling (i.e., "Békésy effect"), they are less prone to biases in their responses, reducing demand characteristics as an explanation for our results. In short, participants received two touches in succession one to each index finger while autosuggesting that the touch on the left, autosuggested finger felt stronger (Experiment 1) or weaker (Experiments 2 and 3) and judged the perception of the frequency of touch on the right, comparison finger. Assuming autosuggestion was successful, and given the relationship between frequency perception and intensity, we expected differences between the *autosuggestion* and *baseline* conditions. Our findings revealed that autosuggestion had different effects depending on participants' frequency-intensity associations. As predicted, for those with a positive association trend (higher intensity leads to higher frequency perception), mentally repeating thoughts of increased intensity on the reference finger led to perceptions of higher frequencies at that finger (Experiment 1), while thoughts of decreased intensity resulted in lower frequency perceptions (Experiment 2) even with a modified mode of responses (Experiment 3). Unexpectedly, in participants with a negative frequency-intensity association (Experiment 2), we found that mentally affirming the perception of weaker intensity on the autosuggested finger, led to perceiving the frequencies at that finger as lower as well. This research offers the first empirical framework suggesting that autosuggestion might produce changes in perception, although with clear limitations. It also highlights the need for further studies to explore the divergent effects observed in groups with positive versus negative associations.

Study 2 (Chapter 4) expanded our investigation by comparing the effects of autosuggestion on tactile intensity perception with placebo, a well-documented phenomenon in clinical contexts (Colloca & Benedetti, 2005; Finniss et al., 2010; Klinger et al., 2014; Pollo et al., 2011; Wager & Atlas, 2015). This comparison is crucial for developing effective mind-body therapies, which often rely on placebo effects. We adapted the experimental paradigm from Study 1, introducing modifications designed to increase the magnitude of the observed effects. Specifically, we included conditioning trials in which some touches were intentionally stronger or weaker than the standard intensity stimuli. This approach was designed to artificially enhance participants' belief in the effectiveness of the autosuggestion or placebo manipulation, increasing their perceived success. We also compared strong versus weak manipulations, predicting greater differences between the two conditions. However, these modifications did not yield the anticipated results, and we observed no significant effects of either autosuggestion or placebo, suggesting that the modifications introduced to the paradigm led to abolishing the effect, at least in the case of autosuggestion. Note here however, that the sample of autosuggestion was very small, limiting effect size and potentially affecting the reliability of these findings.

In Study 1, we showed that autosuggestion was effective in biasing sensory perception of tactile intensities to some extent. We then wanted to extend our research and examine whether autosuggestion can also affect the perception of the spatial configuration of body parts. Thus, in Study 3 we explored the influence of autosuggestion on more complex perceptual phenomena, such as the body schema, a concept referring to a somatosensory aspect of body perception, concerned with tracking and updating the positions of body parts in space during movement (Holmes & Spence, 2004). Specifically, we investigated whether through autosuggestion one could induce ownership over uncrossed rubber hands and thus, impact the perception of tactile stimuli delivered to participants' own crossed hands. We compared three conditions: autosuggesting that the fake hands belonged to the participants, suggesting that they belonged to another person, and a control condition without autosuggestion. The effects were measured by the magnitude of the crossed-hands deficit in a TOJ task. It has been shown that localization of touches is largely impaired with crossed hands as compared to hands uncrossed (Azañón, et al., 2016a; 2016b; Azañón & Soto-Faraco, 2007; Begum Ali et al., 2014). We predicted that the successful incorporation of rubber hands into the bodily self through autosuggestion would contribute to the perceptual merging of the crossed real hands into the position of the uncrossed rubber hands. This perceptual merging, combined with visual feedback showing the hands as uncrossed, was expected to alleviate the impairment typically seen in touch localization when hands are crossed. We also predicted that thinking about nothing specific, while looking at rubber hands placed palms upwards, given the unlikely positioning and the lack of attempts to include it in the body image would lead to poor performance in the TOJ task, similar to what is usually seen in classic temporal order judgment tasks with crossed hands. Our results did not reach statistical significance, which may reflect either the robustness of the crossed-hands deficit and limitations in our methodology or a potential dissociative effect reflecting, in fact, the effectiveness of autosuggestion – the two possibilities that should be investigated in more detail in future research.

Finally, in Study 4 we investigated the effects of autosuggestion on emotion perception. Facial emotions represent more complex and socially relevant stimuli compared to simple tactile sensations, allowing for the exploration of the impact of autosuggestion on higher-order cognitive processes. By expanding research from tactile autosuggestion to visual emotion perception, we can develop a more comprehensive understanding of how top-down cognitive processes, such as autosuggestion, influence our sensory experiences and social cognition. This broader perspective can inspire us to use autosuggestion techniques in clinical and everyday settings. In an adaptation paradigm, participants were instructed to autosuggest that a neutral face looked as happy or sad, and subsequently to evaluate facial expressions of test faces on a happiness-sadness continuum scale. In the first autosuggestion experiment (Experiment 1a) we predicted, that if autosuggestion was successful, participants would perceive subsequently seen faces as opposite in emotional valence to autosuggested emotion, just as it is the case in the traditional adaptation paradigm where participants are adapted to an actual face (Butler et al., 2008; Fox & Barton, 2007; Rhodes et al., 2003; Webster & MacLeod, 2011). We showed a significant influence of autosuggestion. Specifically test faces appeared more similar to autosuggested facial emotion. Interestingly, we observed that participants relied largely on imagery, even though it was stressed to them to avoid creating visual images as much as possible. We thus followed up on this experiment. In one experiment (Experiment 1b: autosuggestion) we used the same paradigm but modified the verbal instructions to restrict the use of visual imagery even more while autosuggesting. In the second experiment (Experiment 2: imagery), we asked participants to imagine a previously seen neutral face as happy or sad. We had no specific predictions concerning the effect of imagery because the literature shows contradictive results (D'Ascenzo et al., 2014; Ryu et al., 2008; Zamuner et al., 2017). We observed that imagery, just as autosuggestion, even with the modified instructions, led participants to perceive subsequent faces as more similar to imagined and autosuggested emotions. Importantly, we ruled out demand characteristics by demonstrating no effects when emotional words were written under the neutral faces (Experiment 3: emotion words). To validate our experimental setup, we successfully replicated standard contrastive aftereffects using happy and sad adapting faces (Experiment 4: perception). These findings underscore the potential for deliberate mental processes to influence the perception of others' emotional expressions.

Taken together, our studies suggest that autosuggestion might influence perception. From the dynamic shaping of tactile experiences (Study 1) to the modulation of emotional valence perception (Study 4), autosuggestion appears to impact sensory and emotion perception. This research provides preliminary evidence of autosuggestion's measurable effects across various cognitive domains, laying the foundation for further scientific investigation of this phenomenon. However, additional studies must be conducted to fully assess and understand the implications of autosuggestion. The next section considers in more detail the possible mechanisms and cognitive processes involved in autosuggestion.

7.2 Potential mechanisms and cognitive processes underlying autosuggestion and their relevance to our findings

Understanding the mechanisms of autosuggestion is essential for understanding how individuals can self-regulate and deliberately change their mental and perceptual states. In this section I will discuss the potential cognitive underpinnings of autosuggestion, exploring how some mental processes such as semantic processing, mental imagery, and attention, might contribute to shaping perception and experience, and how they may have influenced our experimental outcomes. It needs to be noted that the list of the mechanisms underlying autosuggestion is not exhaustive, but to this point, these are the mental strategies that we can discuss in light of our results. By reviewing these cognitive processes, I aim to construct a more comprehensive understanding of how autosuggestion might operate.

7.2.1 Semantic and conceptual processing in autosuggestion

Language offers us a powerful capacity to represent the world (Walsh & Oakley, 2022). The definition of autosuggestion reflects its predominantly linguistic nature, encompassing both semantic content and deeper conceptual processing. It goes beyond a simple recognition of the literal meaning of words or suggestions, as it involves engaging with broader ideas, experiences, and contexts. For instance, when an individual self-suggests “happiness”, the process extends far beyond repeating the word alone, it requires an understanding of what happiness means, including a mental map of associated experiences, emotions, and personal interpretations. Moreover, each individual may construct very different internal representations despite using the same language objectively. This maximizes the impact, turning the suggested internal representation into the actual experience, or so-called “suggested reality” (Walsh & Oakley, 2022).

A growing body of research highlights the role of linguistic context in the formation and maintenance of our perceptions of the world and ourselves in various contexts, including marketing and advertising (Goddard, 2002; Noriega & Blair, 2008), political communication (Dunmire, 2012), or cross-cultural communication (Hennink, 2008). For example, gendered nouns can lead a Spanish speaker to consider a “key” as more feminine, while for a native German speaker, it would be more masculine, and the use of inclusive language (e.g., “we” instead of “you”), can increase audience engagement (Borelli et al., 2018). For instance, informing two different individuals about a prescription for a “newer” drug could produce varying conceptual associations, leading to different outcomes. One individual who associates “newer” with technological advancements may expect and experience an improvement in symptoms. In contrast, another individual who associates “newer” with insufficient testing may expect and experience a deterioration of their condition (Colloca et al., 2023).

Research in clinical settings provides evidence that the linguistic context may alter the subjective experience of pain perception. For instance, Vukovic et al. (2018) investigated the effects of linguistic constructions on pain perception in people with chronic migraine and healthy controls. In a priming task, participants first read sentences either with literal or metaphorical pain descriptions, and after that, they rated the intensity of thermal painful stimuli. Results showed that the use of literal language influenced pain intensity perceptions more than metaphors. In addition, the effect of language on pain perception varied depending on the individual pain history: chronic pain patients showed hyperalgesic effects more strongly than controls. Moreover, rising neuroimaging evidence supports the claim that words activate different brain networks depending on their painful connotation, valence, or context (Osaka et al., 2004; Richter et al., 2010). These findings highlight how the choice of language in clinical settings can significantly affect health outcomes, emphasizing the need to avoid “language traps” when communicating with patients (Schenk, 2008).

Inspired by the abovementioned examples, about the importance of the choice of words used in suggestion, in Chapter 2 (see also Myga et al., 2022) we proposed a set of guidelines regarding linguistic strategies to perform autosuggestion effectively. We designed these guidelines to optimize the formulation of self-suggestions, ensuring that individuals can engage with the process in a more structured and effective way. Consequently, we used these guidelines to teach participants how to perform autosuggestions in all of our experiments. In this way, we aimed to create a standardized approach to performing autosuggestion across our studies, by making sure that participants showed consistency in applying their suggestions. However, despite these instructions, we observed that, rather than following instructions, participants modified their autosuggestion process according to their own preferences, which will be discussed in more detail in the sections that follow.

Another important factor of our definition of autosuggestion is the emphasis on the intentionality of the suggestions used. Indeed, we showed that in the context of autosuggestion, simply being exposed to a concept or word is not enough to produce meaningful effects. In Study 4, when participants actively employed autosuggestion or mental imagery to change their perception of neutral emotions, their subsequent interpretations of facial expressions shifted toward the emotion they had suggested or imagined. However, when an emotion concept was only passively presented, by displaying the word "happy" or "sad" below a neutral face, participants' perceptions did not change, even when participants reported seeing these words, and many reported analyzing their content in various ways. This distinction suggests that the phenomenon of autosuggestion depends on different cognitive processes that go beyond simple semantic processing and require an active will and intention to experience the desired states.

Moreover, thought repetition and continuous focus on the suggested concept seem to be essential components of successful autosuggestion. This seems to be evidenced by the null results in Study 3, in which participants autosuggested the ownership of the rubber hands, but in that experiment, autosuggestion was interleaved with the tactile TOJ task. Indeed, debriefing after the experiment revealed that the autosuggestion process had indeed been disrupted during the tactile task, which may thus have contributed to the null results. This, however, was not the case in Study 1 on autosuggestion concerning tactile perception. Even though participants reported that, compared to *baseline*, the *autosuggestion* condition in that study was highly demanding, as they were required to divide their attention between the tactile and autosuggestion tasks, to ensure the continuity of repetition and concentration on the suggestion. Nevertheless, participants reached the desired outcome, at least in the positive association group.

In summary, our studies support the claim that the choice of language and the integration of semantic and conceptual content is an important factor in the autosuggestion process. Notably, we report for the first time in the literature that participants, despite being instructed to use only one strategy (i.e., verbal autosuggestion), they often struggled to comply with the instructions and frequently supplemented autosuggestion with other mental strategies. In the next section, I will further discuss the most frequently employed strategy during the autosuggestion process, namely mental imagery.

7.2.2 Involvement of mental imagery during autosuggestion

In all our experiments we explicitly asked participants to refrain from using mental imagery, as this is considered another mental process (Kosslyn et al., 1995) that we differentiated in detail from autosuggestion in Chapter 2. We explained to the participants the differences between autosuggestion and mental imagery, and all participants reported comprehension of these distinctions and agreed to adhere to the instructions. However, post-experiment questionnaires revealed that the majority of participants generated some kind of mental imagery, predominantly in Study 4.

For instance, in Study 4 participants made pictures in their mind's eye of the identity of the face autosuggested. Moreover, they created elaborate visual scenarios as if they were watching the person in a movie, or even imagined themselves or their family and friends expressing autosuggested emotions in relevant circumstances. The level of imagery used in the tactile experiments, especially in Studies 1 and 2, was used to a lesser extent, and involved, for instance, imagery of pain to induce a stronger feeling of touch (Study 2).

The fact that participants supported their outcomes by using visual imagery could be attributed to participants' misunderstanding of the differentiation between autosuggestion and imagery, or to using both words interchangeably for the tested phenomenon. Indeed, when the experimenter asked them whether they understood the task and they paraphrased the instructions using the word "imagine" instead of "autosuggesting" – the experimenter paused and asked them for clarification of the term used, which finally led to agree that they meant autosuggestion.

It may also be linked to the brain's natural inclination to generate vivid mental representations, which could indeed be an important component in the efficacy of autosuggestion, at least in individuals with high imagery abilities, who are naturally inclined to operate in visual images. Some participants indeed admitted to considering themselves as "highly visual" and shared in their post-experiment feedback, that they favor visual information processing over verbal repetition. Moreover, the consistent emergence of mental imagery across participants suggests that it may play a supportive role in the autosuggestion process through several key mechanisms, listed below.

First, neural activation – mental imagery activates neural networks similar to those engaged during actual perception and experience, albeit weaker in amplitude (Ganis et al. 2004; Kosslyn et al. 1997; Kuehn et al. 2014; Schmidt and Blankenburg 2019; Senden et al. 2019). This is essential for autosuggestion, as one aims to produce the perception of states that are absent due to the lack of relevant physical stimulation. In other words, one tries to override current perceptual states toward percepts conflicting with those produced via current sensory input. Mental imagery can play a supportive role in autosuggestion, as it facilitates the neural overlap between the imagined and actual brain states. Mentally imagined states, which are usually evoked without specific personal intention such as imagining a letter (Senden et al., 2019) or an item (Segal, 1971), or performing a certain activity (Neuper et al., 2005), allow the brain to "pre-experience" suggested states in the mind's eye, making the imagined scenarios feel more real and perceptually probable. Coupling imagery with the purpose and intention in the autosuggesting process might help to activate neural pathways that mimic perceptual states according to one's will and bring them to the current experience.

Second, imagery as well as autosuggestion, are top-down processes, where higher cognitive functions influence sensory perception and bodily responses. In autosuggestion, the higher cognitive functions are biased by the deliberate use of verbal suggestions. Thus, when individuals incorporate mental imagery into autosuggestion by creating vivid and detailed mental representations of the desired outcome, they potentially enhance their ability to focus on the suggested state. Therefore, adding imagery may enrich the internal experience, making it more compelling and engaging. This multimodal approach (verbal repetition coupled with visual mental images) potentially amplifies the modulation, thereby reinforcing the effectiveness of the autosuggested state.

Third, imagery can amplify emotional and psychological responses (Pictet & Holmes, 2013), as imagined content contains references to sensory representations (Holmes & Mathews, 2005). For instance, imagining a protective glove on the forearm was shown not only to reduce the perception of painful stimuli but also to rate the stimuli as more pleasant (Fardo et al., 2015). Also, imagining a friendly encounter with an immigrant reduced the levels of hostility toward outgroup members (Brambilla et al., 2012). In the literature, it is thus common to ask participants to imagine a specific scenario (e.g., moving from cold air to a warm place and sitting near a stove) and evaluate its effects on subsequent perception (e.g., relaxation; Min et al., 2005). As noted already in previous sections, these states (i.e., touch pleasantness, positive attitude toward an outsider, emotional arousal) are often unintended byproducts of imagery rather than the primary goal of the intervention. However, when deliberately integrated into autosuggestion, these "byproducts" of the imagined content could help make autosuggested states more compelling and increase the effectiveness of autosuggestion through evoked sensory stimulation (Wicken et al., 2021).

It is also important to note, that whereas imagery of a positive subjective valence can be intentionally integrated in the autosuggestion process, in certain situations we could observe intentional separation between imagery and autosuggesting. Specifically, in the case of spontaneously experiencing distressing images usually in clinical populations such as in the case, for instance, of experiencing intense pain (Berna et al., 2012), PTSD symptoms (Brewin et al., 2010), and phobia (Hackmann et al., 2000), anxiety (Hirsch & Holmes, 2007) or depression-related (Patel et al., 2007) scenarios. In such context, this uncontrollable, intrusive imagery (Patel et al., 2007) is regarded as a key driver for negative emotion (Wicken et al., 2021). Incorporating autosuggestion in the treatments of these conditions could be used to disrupt the thought processes leading to the creation of negative images by deliberately thinking about more positive content leading to the creation of more supporting imagery. It would be interesting to test this idea in future studies.

In summary, based on the evidence provided in the literature as well as our own findings, mental imagery seems to play an enhancing role in autosuggestion possibly by engaging similar neural pathways as real experiences, modulating sensory perceptions using top-down influences, constructing detailed internal models, and evoking emotional responses. By creating vivid and convincing scenarios, mental imagery implemented in autosuggestion could help to shape the self-suggested outcomes into more tangible and realistic internal experiences. Given the significant role of imagery in our experiments, it would be interesting to test individuals with aphantasia – those who cannot voluntarily create mental images (Monzel et al., 2023). Studying this group could offer valuable insights into the effects of verbally repeated suggestions only, and whether alternative mechanisms could be at play in achieving similar outcomes.

7.2.3 The role of attentional processes in autosuggestion

Autosuggestion assumes focusing on the desired outcome while inhibiting and “overriding” competing perceptual representations. Attentional processes are therefore implicated in the outcomes of autosuggestion. Already Coué proposed the “Law of Concentrated Attention” regarding autosuggestion, where ideas upon which attention becomes focused become correspondingly magnified in their effect. Conscious autosuggestions must be repeated with mental focus and concentrated attention for them to be effective. However, the involvement of attentional processes in autosuggestion is not straightforward or documented.

It has been established that simply directing attention to specific body parts can enhance sensations (Gomez-Ramirez et al., 2016; Longo et al., 2009) and leads to increased activity in related sensory neural networks (Burton & Sinclair, 2000). Building on this, we would expect that directing attention inwardly to tactile stimuli and intending them to feel stronger, would amplify effects beyond simple attentional effects, due to concentrated will and intention. This aligns with findings from Study 1, Experiment 1, where autosuggesting that touch felt stronger led to perceiving frequencies of the stimuli as higher, as compared to baseline. Moreover, participants reported that one of their main strategies used was focusing attention on their autosuggested fingers. We also observed that autosuggesting stronger perception was easier than autosuggestion that the touch felt weaker (Study 2, Experiment 2). However, autosuggestion has also produced results where participants directed their attention to reduce the perceptual intensity of touches.

These results raise a complementary question: How did autosuggestion lead to the perception of reduced sensation in the *weak* condition in Study 1 (Experiment 2, participants with a positive association), even when participants directed their attention specifically to the finger? This outcome of autosuggestion contradicts expectations based on evidence from the attentional literature, which typically suggests that directing attention towards a body part enhances perception (Gomez-Ramirez et al., 2016; Longo), while diverting attention yields the opposite effect (Eimer et al., 2004).

Unfortunately, no evidence exists to support the possible explanation for this question, and it can only be approached hypothetically. If we were to follow assumptions underlying attentional processes theories, in the attentional paradigm, to reduce the perceived intensity of touch, participants would most likely use strategies such as diverting attention away from the stimuli or thinking about things unrelated to the task. This would be reflected in the results, wherein the *weak* conditions we would observe flatter psychometric functions, compared to the *strong* or the *baseline* conditions. However, in our experiments, participants were asked to direct their attention equally toward the stimulus in both *strong* and *weak* conditions.

The results showed that the slopes of psychometric functions were similar, assuming equal attention allocation in both *strong* and *weak* conditions. Moreover, to control for attentional engagement to tactile tasks, in Study 2 we introduced catch trials where the frequency on both the reference and comparison fingers varied. This contrasted with the standard trials, where the frequency remained the same. By this, we were able to calculate the trials where participants correctly judged the frequency on the comparison finger as being higher or lower than the frequency on the reference finger, and the higher number of correct responses suggested that participants highly engaged their attention, at least on the tactile task (i.e., judging the perceptual frequency comparison between both fingers). We found that participants accurately judged frequency differences, with an average accuracy collapsed across the two conditions (i.e., *strong* and *weak*) of 92.3% in Experiment 1 and 90.66% in Experiment 2. These results are significantly above the chance level, further reinforcing the premise that participants' attention was equally distributed across tactile tasks, even when instructed to reduce sensations. Although attentional engagement was not tested in Study 1, we can assume these results generalize to the previous samples tested, given that participants were recruited from the same cohort, predominantly consisting of university students in Magdeburg.

One mechanism responsible for our results referring to the reduction in perception could be "perceptual decoupling", a mechanism responsible for decoupling attention from the perception of external events (Smallwood & Schooler, 2006). This concept is usually discussed in the context of mind wandering, where individuals shift their attention from the task at hand into the internally generated train of thoughts unrelated to the task performed (Christoff et al., 2016). In autosuggestion, perceptual decoupling might be implied in dissociating participants' perception of sensory stimulus, towards inwardly created characteristics via intended thought repetition.

For example, in our tactile Study 1, participants were able to attend to tactile stimuli sufficiently to perform the frequency perception task, but they relied on internally generated perceptions of tactile intensity stimuli. Similarly, in the autosuggestion experiment in Study 4 (Experiments 1a and 1b, autosuggesting happy and sad emotions), participants were instructed to focus their attention on specific parts of adapting faces while verbally repeating relevant autosuggestive phrases. They appeared to disregard the actual visual stimuli, suggesting a decoupling from direct perception while still attending to the stimulus. For instance, they might perceive the corners of the lips as higher up, indicating a smile in the *happy* condition, or lower down, suggesting sadness in the *sad* condition. Also, as supported by self-reports, perceptual decoupling was most likely responsible for null effects observed in Study 3, where participants autosuggested the ownership of the rubber hands, and in consequence "disowned" their own hands.

However, it should be noted that while perceptual decoupling in mind wandering typically involves a spontaneous and uncontrolled shift of attention away from external tasks and towards inner thoughts, in autosuggestion, participants continue to actively process external stimuli, suggesting that decoupling might occur at a different stage of cognitive processing. This hypothesis calls for further empirical investigation.

To conclude, attentional mechanisms likely play an important mediating role in autosuggestion, beyond just directing attention, though the exact mechanisms are still to be understood. Future studies could explore individual differences in attentional control and its interaction with suggestibility to provide further insights into the variability observed in responses to top-down manipulations. For instance, individuals with superior attentional control abilities could exhibit heightened susceptibility to autosuggestion, as they can more effectively direct and sustain their attentional resources towards the suggested perceptual outcomes while inhibiting contradictory inputs. Future research should also consider incorporating direct measures of attention and cognitive load of the experimental task to better understand perceptual biases observed in autosuggestion experiments.

7.3 Is autosuggestion a genuine phenomenon? – conclusions and recommendations for future research

Is autosuggestion a genuine phenomenon? At this stage of our research, we are not able to say with certainty that autosuggestion, as defined in this thesis, does indeed represent a well-proven mental tool. However, it is also too early to reject autosuggestion's effectiveness. In the light of our studies, the answer to this question is ambiguous. In our first tactile study, we showed the expected effects of autosuggestion but only in the positive association group. However, slight adjustments to the previously working paradigm abolished the effects in Study 2. Moreover, in Study 2, we observed no effects of placebo manipulation, even though placebo is a well-established phenomenon in the existing literature (Colloca & Benedetti, 2005; Finniss et al., 2010; Klinger et al., 2014; Pollo et al., 2011; Wager & Atlas, 2015). We could also not show that autosuggestion can change proprioception, as evidenced by null results in Study 3, although these results might reflect other outcomes, such that perhaps autosuggestion worked by dissociation of the own hands rather than merging them perceptually with rubber hands (see discussion Chapter 5). Finally, in Study 4 we did show clear effects of autosuggestion on emotion perception. Despite these inconclusive results, this novel and carefully designed research offers significant insights into the impacts of autosuggestion.

In this section, I will concentrate on the takeaways of our findings and how they contribute to the research on autosuggestion. When appropriate, I will address limitations and propose possible solutions to them. It should be noted that each study chapter ends with a thorough discussion about the effects of autosuggestion dedicated to the specific context. Here, I do not aim to repeat what was already mentioned above but rather briefly draw global conclusions.

It's important to note that our research is innovative, as we could not model already established successful paradigms, rather, we ought to develop a new experimental framework. For this aim, we not only carefully designed the experimental paradigms to employ in our studies, aiming mainly at reducing the possibility of demand characteristics, which are so prevalent in the limited number of studies on autosuggestion (Ludwig et al., 2014; Sari et al., 2017; Schlamann et al., 2010; Shilpa et al., 2020), but we also directly asked participants about the nature of their engagement and their experience in autosuggestion at the end of experiments. This approach allowed us to gain insight into what actual cognitive processes were reported during testing autosuggestion, and not concluding, based solely on the experimental assumptions and behavioral data, that the effects observed are indeed the results of autosuggestion as we define it.

One significant finding, observed to varying degrees across tested samples, is that most of the participants used mental imagery and other supporting cognitive strategies during autosuggesting. For instance, participants frequently contextualized autosuggestion by imagining themselves or significant others – such as family and friends – in scenarios that supported the elicitation of the desired emotional or sensory states, they would also switch into their own language or sing to themselves in their mind's eye. This occurrence was against the autosuggestion definition we proposed in Chapter 2, and instead of the standardized procedure that we aimed for, we observed great variability in all the results. Nevertheless, these findings are important, as they point out the importance of the collection of self-report data to differentiate between participants' actions in the experimental task versus what was required of them, especially during the tasks involving top-down processes.

Participants' persistence in integrating verbal repetitions with other cognitive strategies in the varying experimental settings, challenges the definition of autosuggestion, which we proposed based on the theoretical findings only (see Chapter 2), and perhaps we should be open to adapting a modified autosuggestion definition.

Certainly, autosuggestion involves self-directed suggestion, an essential aspect of the definition, that is irrevocable. Suggestions made to oneself fall under the same laws as our initial definition – they are self-induced willingly and intentionally, aiming at changing and overriding existing perceptual or brain states, into the new desired states. The word "auto" in autosuggestion should perhaps also refer to "auto" in the sense of self-choosing which cognitive strategies and mental modalities work best for the person performing autosuggestion. In other words, one should be free to choose what strategies they prefer to employ in autosuggesting to get the most reliable results. For one it could be creating vivid images in one's head, for another it could be evoking strong bodily feelings, yet for someone else the mixture of both would be ideal. As long as the process is directed to changing perceptual processes "in the moment" and according to one's will, it still distinguishes autosuggestion from similar cognitive phenomena evoked spontaneously without intention, or during experimental settings without the goal of changing someone's current experience. We are currently employing this *free-autosuggestion-strategy* approach to test the effects of autosuggestion in the follow-up experiment for Study 3 (i.e., changing body schema perception), which falls out of the scope of this thesis.

Indeed, allowing free-style autosuggestion as opposed to the standardized autosuggestion procedure that we advocated earlier following the initial definitions of Coué, at least in the experimental setting, might lead to greater variability of results, which indeed is reflected in our observations. However, this can be overcome by testing larger cohorts than we tested in our experiments, which may lead to discovering trends in responses between participants characterized by specific personality traits.

Indeed, literature on heterosuggestion such as hypnosis and placebo, is rich in evidence showing great variability in results, due to, for instance, people's suggestibility traits (Parris, 2016) or self-efficacy and expectations (Kirsch, 1999). It is thus crucial to include these measures in research on all types of suggestions. Similar factors are expected to influence the results of autosuggestion, at least to a certain extent. Even though we included some of those measures in our experiments, such as suggestibility traits, imagery skills, or questions measuring participants' beliefs about their expected (i.e., self-efficacy measure) or obtained (i.e., subjective outcome measure) outcomes, these results served us only as exploratory measures. Our studies were not focused on interindividual differences, and the in-depth analyses of those reports fell beyond the scope of discussion in this doctoral work. These factors deserve, however, future investigation in a large cohort of participants. Replicating our studies with larger samples could cast more light on our seemingly inconclusive results. These studies could find more distinctive effects, depending on the characteristics of sub-samples; the effects that might have been hidden from view in our experiments.

Moreover, incorporating neuroimaging techniques such as functional magnetic resonance imaging (fMRI) or electroencephalography (EEG) could provide a deeper understanding of the neural mechanisms underlying autosuggestion and how they might differ from other related phenomena. fMRI studies could help identify the specific brain regions and networks involved in autosuggestion, potentially revealing the involvement of sensory cortices, cognitive control networks, and regions associated with interoceptive awareness and self-regulation. EEG, on the other hand, could elucidate the temporal dynamics and oscillatory patterns associated with autosuggestion, shedding light on the neural processes underlying the instantiation, reiteration, and maintenance of autosuggested states. Furthermore, combining neuroimaging techniques with measures of physiological arousal, such as skin conductance or heart rate variability, could provide insights into the potential influence of autosuggestion on autonomic nervous system activity and the mind-body connection.

In conclusion, our exploration of autosuggestion has yielded interesting insights, even as it has raised new questions and challenges regarding its definition and experimental investigation. While the findings of our studies were inconclusive, they highlight the complexity of the phenomenon and the need for further inquiry. The persistence of participants in integrating mental imagery and other cognitive strategies suggests that the process of autosuggestion may be more sophisticated than we initially thought. It involves not only verbal affirmations but also a flexible use of cognitive modalities tailored to individual preferences and needs. This adaptability may be both a strength and a challenge for empirical research, necessitating refined experimental designs and larger, more diverse samples to account for interindividual variability.

Future studies should consider this complexity by expanding the methodological toolkit and incorporating neuroimaging techniques such as fMRI and EEG to uncover the neural mechanisms underlying autosuggestion. Additionally, investigating the interplay between individual differences – such as suggestibility, imagery vividness, and self-efficacy – and the efficacy of autosuggestion could provide valuable insights into its variability and potential for customized interventions. By addressing these issues, we can move closer to closing the gap in the literature that was identified at the beginning of this thesis. Although definitive conclusions remain elusive, this work provides a foundation for continued exploration and the potential refinement of autosuggestion as a scientifically and practically relevant construct. If the effects of autosuggestion can be reliably demonstrated and the underlying mechanisms understood, in the realm of self-development, autosuggestion techniques could be employed as a means of enhancing cognitive performance, emotional regulation, or even physical abilities, by enhancing the mind's capacity to shape perception and experience. Autosuggestive techniques could also be developed as non-pharmacological interventions supporting standard medical treatments, where autosuggestion could empower patients to take a more active role in their recovery and well-being.

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Annexes

Annex 1: The article "Myga, K. A., Azañón, E., Ambroziak, K. B., Ferrè, E. R., & Longo, M. R. (2024). Haptic experience of bodies alters body perception. *Perception, 53*(10), 1-14. https://doi.org/10.1177/03010066241270627".

Article

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Haptic experience of bodies alters body perception

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Abstract
Research on media's effects on body perception has mainly focused on the role of vision of extreme body types. However, haptics is a major part of the way children experience bodies. Playing with unrealistically thin dolls has been linked to the emergence of body image concerns, but the perceptual mechanisms remain unknown. We explore the effects of haptic experience of extreme body types on body perception, using adaptation aftereffects. Blindfolded participants judged whether the doll-like stimuli explored haptically were thinner or fatter than the average body before and after adaptation to an underweight or overweight doll. In a second experiment, participants underwent a traditional visual adaptation paradigm to extreme bodies, using stimuli matched to those in Experiment 1. For both modalities, after adaptation to an underweight

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body test bodies were judged as fatter. Adaptation to an overweight body produced opposite results. For the first time, we show adiposity aftereffects in haptic modality, analogous to those established in vision, using matched stimuli across visual and haptic paradigms.

Keywords
adaptation aftereffects, haptic perception, body perception, touch

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Negative attitudes toward the body and dissatisfaction with the size and shape of the body are pervasive in modern society. Dolls and mass media portrayals, including "size zero" models and the unrealistic Barbie dolls, are thought to contribute to the development of body image concerns (Boothroyd et al., 2021; Derenne & Beresin, 2006; Jellinek et al., 2016; Rice et al., 2016), occurring at a young age (Truby & Paxton, 2002). Playing with dolls provides children with a tactile and intimate sense of the shape and proportions of bodies (Thompson et al., 1999; Urla & Swedlund, 2007). While existing research has predominantly examined the visual aspect of media's influence on body perception, other sensory perceptual modalities, such as haptics, have been neglected. Here we investigate how haptic experience of extreme body shapes affects body perception, and how this compares to experience in the visual domain. We first explore the effects of haptic adaptation to underweight or overweight dolls on the subsequent perception of the shape (adiposity) of bodies. We then investigate how the magnitude of such haptic aftereffects relates to corresponding adaptation in vision.

Adaptation aftereffects are systematic changes in perception resulting from prolonged exposure to specific types of stimuli. They have been called "the psychologist's microelectrode" (Frisby, 1979) on account of the revealing window they provide into the organization of perceptual processes. Adaptation aftereffects resulting from visual exposure to extreme body types have been widely studied and found to affect judgments of body attractiveness (Boothroyd et al., 2012; Mele et al., 2013; Winkler & Rhodes, 2005) and normality (Glauert et al., 2009; Hummel et al., 2012; Winkler & Rhodes, 2005). These effects have been found to transfer across identities: adaptation to the thin/fat body of another person produces aftereffects on visual judgments of one's own body size (Ambroziak et al., 2019; Brooks et al., 2016; Hummel et al., 2012). Adaptation, therefore, can change people's perceptions of bodies and may lead to developing mental disorders (Stephen et al., 2018). These studies demonstrate that perceptual adaptation is a rich tool for probing the effects of extreme body types on body perception. Accordingly, Brooks et al. (2020) have recently argued that short-term visual adaptation aftereffects may function as an experimental model of the well-established effects of mass media depictions of bodies on body image.

In vision, the finding of adaptation aftereffects for body size had provided clear evidence that the visual system rapidly and automatically processes features of bodies specifying individual differences in body size. It is unknown whether similar adaptation aftereffects emerge following haptic experience of extreme body types. From a theoretical standpoint, it may be that haptics provides different types of information about bodies than vision. The visual and haptic modalities have different limitations and advantages given the fundamental differences in how they encode physical stimuli. Compared to vision, haptics appears to code features of the physical substance of objects, such as how hard/soft or smooth/rough they are, more effectively than more global object shape (Klatzky et al., 1987). This haptic bias for coding texture rather than shape has also been found in the case of haptic face recognition (Kilgour & Lederman, 2002). From this perspective, adaptation aftereffects for body shape would be expected to be absent, or at least substantially reduced compared to those found in vision.

Alternatively, it may be that both vision and haptics code individual differences in body form in similar ways, which would predict that comparable adaptation aftereffects may be found in both modalities. There is substantial evidence that visual and haptic object perception involve similar neural mechanisms. Neuroimaging studies have shown that regions of the ventral visual pathway, such as the lateral occipital complex, are activated by haptic object perception in a similar way as in vision (Amedi et al., 2001, 2002; James et al., 2002). The same appears to be true of category-selective regions of the ventral pathway originally identified with visual stimuli, which show similarly category-selective responses in haptics (Pietrini et al., 2004). This pattern has been found in the fusiform face area (James et al., 2006; Kilgour et al., 2005; Kitada et al., 2009), the parahippocampal place area (Wolbers et al., 2011), and for body parts in the extrastriate body area (Costantini et al., 2011; Kitada et al., 2009). Similarly, there are numerous cases in which object recognition deficits (agnosia) following brain damage occur for both visual and haptic stimuli (Feinberg et al., 1986; Ohtake et al., 2001; Sirigu et al., 1991). At the same time, however, agnosia in the two modalities can be doubly dissociated, with reports of modality-specific agnosia in both vision (Allen & Humphreys, 2009; Riddoch & Humphreys, 1987; Snow et al., 2015) and haptics (Reed et al., 1996; Veronelli et al., 2014). Together, these results indicate that there are deep similarities between haptic and visual object recognition, but also important differences.

Answering whether similar adaptation aftereffects to vision emerge following haptic experience of extreme bodies has important implications for understanding the mechanisms underlying body perception. It also has more practical implications in understanding the factors underlying the emergence of body dissatisfaction given that haptic experience is a major way in which children perceive dolls. While no research has investigated haptic adaptation aftereffects for bodies, there is evidence that similar aftereffects emerge following visual and haptic exposure to facial expressions of different emotions (Matsumiya, 2012, 2013) or of different identities (Dopjans et al., 2009). We thus hypothesized that comparable adaptation aftereffects would occur following haptic and visual exposure to extreme body types.

To answer this question, we used 3D printed physical figures that varied in body adiposity in a biologically-realistic way to create a continuum of body shapes from underweight (body mass index [BMI] = 13) to overweight (BMI = 35). In Experiment 1, we adapted female participants either to an underweight (BMI = 13) or to an overweight (BMI = 35) figure explored haptically, and then asked them to judge whether subsequently presented body models were fatter or thinner than an average female body. In Experiment 2, we used a similar procedure with matched visual stimuli to directly compare the magnitude of adaptation aftereffects in the two modalities. To anticipate our results, we find clear adaptation aftereffects following adaptation to both underweight and overweight bodies in both the haptic and visual modalities.

Experiment 1

Method

Participants. Forty female members of the Birkbeck community participated, 20 in each of the two adaptation groups. Due to the nature of the stimuli all representing female body shapes, only women were recruited. Participants in the *underweight adaptation* group were on average 25.3 years old (SD: 4.8) and 19 were right-handed as assessed by Edinburgh Handedness Inventory (Oldfield, 1971; *M*: 77.5, *SD*: 41.5). Participants in the *overweight adaptation* group were on average 24.6 years old (SD: 7.6), and 3 were ambidextrous and the rest were right-handed (*M*: 74.0, *SD*: 26.6). All participants gave informed consent and were paid for their participation.

The procedures were approved by the Department of Psychological Sciences Research Ethics Committee at Birkbeck, University of London.

Our sample size was chosen to be in line with our previous study using a similar paradigm with visual body stimuli (Ambroziak et al., 2019). We used a sample-size weighted average of the effect sizes in the three experiments of that study (using paired *t*-tests comparisons across the point-of-subjective-equality (PSE) means in the adaptation and baseline conditions). Note that *Self* versus *Other* means were collapsed in all experiments of that study. This gave a mean of $d_z = 2.225$, a very large effect size. A power analysis using G*Power 3.1 software (Faul et al., 2007) using this effect size and alpha of .05 showed that only four participants were needed for power of .95. Indeed, our sample size would give power of more than .95 even if the effect size for haptic adaptation was only half that we found for visual stimuli in our earlier study.

Stimuli. We created tactile stimuli using a 3D printer (Ultimaker 2+, Ultimaker B.V.) from the 3D avatars which were designed for our previous study investigating visual adaptation aftereffects (Ambroziak et al., 2019). Full details about the creation of these visual models can be found in Ambroziak et al. (2019). To briefly summarize, we used Daz Studio 4.8 software to manipulate the default Genesis 3 avatar to have different body shapes by manipulating waist-to-hip ratio to approximate BMIs based on formulas provided by Cornelissen et al. (2009). Note that the BMIs given to the avatars are approximations and may not align exactly with real BMIs in the physical world. Indeed, these virtual BMIs are overestimated when compared to real bodies. These discrepancies in the adaptation protocols across modalities might influence the observed strength of adaptation aftereffects, which appeared similar across modalities in this study. Future research could explore this further to systematically investigate how specific modifications impact the magnitude and characteristics of aftereffects across different sensory modalities.

To prepare the models for printing, Meshmixer (Autodesk Inc.) and Cura (Ultimaker B.V.) software were used. The height of each figure was 15 cm. The range of haptic stimuli was between BMI 13 and BMI 35 with a step size of two units, resulting in 12 stimuli in total (see Figure 1). The underweight adaptor stimulus had BMI 13 and the overweight adaptor had BMI 35. The 3D printed stimuli were based on the same underlying 3D models as the visual stimuli, making them closely matched in terms of body shape. We did, however, slightly change the posture of the arms, bringing them closer to the body with the hands touching the hips. This change was required to maintain the structural integrity of the body stimuli during the 3D printing process. In addition, the hair and clothing in the visual stimuli were added during visual rendering of the 3D model, and so were not included in the haptic stimuli.

Procedures. Participants were blindfolded and sat at a table in front of the researcher, who handed the stimuli to them. Participants were not allowed to see the stimuli at any point until the end of the experiment. There were 120 trials in total, 60 in each of the baseline and adaptation blocks. The baseline condition was always presented first to avoid the transfer of adaptation aftereffects across conditions.

Participants were not informed using the terms "adaptor" or "test stimuli." Instead, references were made to "the first and second doll." Additionally, participants were not informed about the size of the adaptor. They were consistently instructed to evaluate only the second stimuli in each pair, independently of the characteristics of the first doll. In the baseline block, on each trial, the participant was handed a figure to explore haptically with both hands for 5 s. Informal pilot testing showed that this amount of time was sufficient, and participant became frustrated if forced to explore the stimuli for more time before responding. Previous research on haptic object recognition has found that more than 90% of responses in a freely timed task were made in less than 5 s (Klatzky et al., 1985). Other research has shown that haptic object recognition

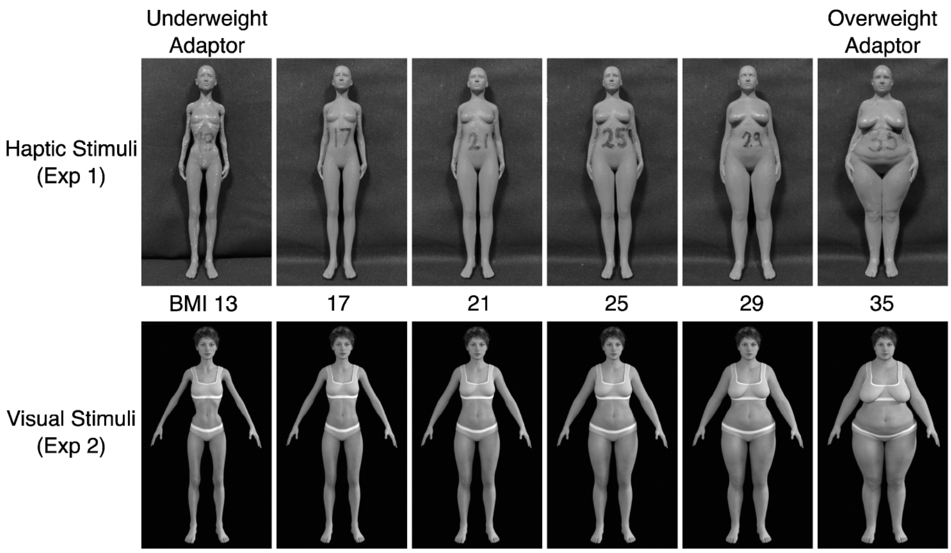

Figure 1. Example of stimuli used in experiments 1 (top panel) and 2 (bottom panel). Both modality stimuli represent the same identity, haptic stimuli were 3D printed based on 3D models of visual stimuli. Stimuli ranged from 13 to 35 in steps of two BMI units (12 in total) for the haptic adaptation experiment, and in steps of 0.25 for the visual adaptation experiment (89 in total). BMIs 13 and 35 were used as adaptors in the underweight and overweight adaptation groups, respectively.

remains highly accurate even when duration of exploration is severely constrained (Klatzky & Lederman, 1995). After verbal instruction from the experimenter that 5 s passed by, they returned the stimulus and made a verbal judgment of whether the body that they touched was fatter or thinner than an average female body of their age. We narrowed the age criterion to avoid possible confusion from trial to trial as to which ‘average’ the test body should be compared to. For instance, the average female body of a woman of 20 years will differ significantly from the average body of a woman in her 50s. Thus, by refining the age of an average body to which test stimuli were compared to, we minimized data variability. Participants responded verbally and the experimenter entered their responses into the computer.

In the adaptation block, participants first spent 1 min haptically exploring the adapting stimuli. $N = 20$ participants received the underweight adaptor and the other $n = 20$ the overweight adaptor. Each trial started with 6 s of “top-up” adaptation before the participant was handed the test stimulus for that trial.

The experiment was controlled by a script written in MATLAB (Mathworks, Natick, MA). The test stimulus for each trial was chosen by the Bayesian QUEST algorithm (Watson & Pelli, 1983) implemented in the Psychtoolbox (Brainard & Vision, 1997; Kleiner et al., 2007), taking into consideration the participant’s previous judgements to identify the most informative stimulus to present. Two staircases of 30 trials each were presented interleaved on a trial basis in a randomized order. One “staircase” started with a prior estimate of a BMI of 19 and the other with a BMI of 31. The BMI of the body perceived as average was calculated as the mean of the posterior probability density function (i.e., a possible threshold value relative to the prior guess, taking under consideration information about assumptions, prior estimates and data), using the QuestMean function in the Psychtoolbox (algorithm by Watson & Pelli, 1983). To make sure that participants understood the difference between baseline and adaptation tasks, they performed four practice trials before starting the adaptation condition.

Analysis. Four PSEs for each participant were calculated using QUEST (Watson & Pelli, 1983) to estimate the BMI at which participants were equally likely to respond thinner or fatter: two for the baseline condition, each corresponding to the results of one interleaved staircase (pre-test dependent variable) and two for the adaptation condition (post-test dependent variable). Next, the two PSE values for each condition were averaged. Paired sample *t*-tests were used to compare these two values, with Cohen's d_z as a measure of effect size.

A 2 × 2 mixed analysis of variance (ANOVA) was used to compare the two conditions. The factors were *adapting body type* (underweight, overweight) as a between-subjects factor, and *adaptation* (baseline, adaptation) as a within-subjects factor.

All data and analysis scripts have been made publicly available via OSF and can be accessed through the following link https://osf.io/gaefz/?view_only=1cac93d5ec794f79ab46324635cb1280. The design and analysis plan for the experiments were not preregistered.

Results

Clear aftereffects were apparent in both the thin and fat adaptation groups, as shown in Figure 2. Adaptation to an underweight body produced subsequent bodies to be judged more often as overweight. This was observed by a shift of PSE in the direction of the adaptor. In particular, the mean PSE decreased from 25.1 (SD: 2.2) to 22.2 (SD: 3.1), $t(19) = 4.78$, $p < .001$, $d_z = 1.068$. Conversely, following adaptation to an overweight body, the mean PSE increased from 24.9 (SD: 1.7) to 27.4 (SD: 2.0), $t(19) = 5.78$, $p < .001$, $d_z = 1.292$, which indicates that participants judged subsequent bodies more frequently as slimmer as compared to baseline. These results show the characteristic "contrastive" adaptation aftereffects which have been repeatedly found for visual adaptation to images of

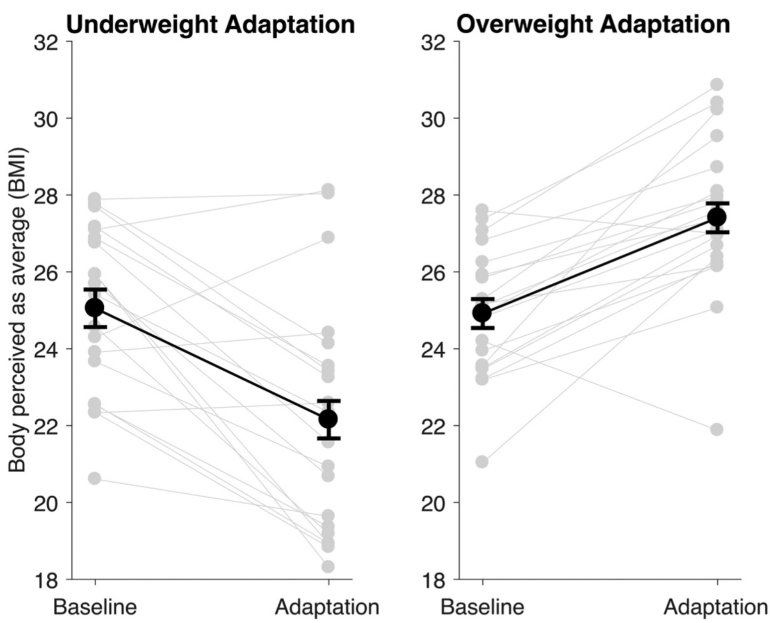

Figure 2. Results for underweight and overweight adaptation in the haptic modality. The gray lines indicate individual participants, and the means are shown in black. *Left panel:* there was an effect of adaptation in the underweight adaptation group, such that the PSE after adaptation significantly decreased, as compared to baseline. *Right panel:* there was an effect of adaptation in the overweight adaptation group: there was a significant increase in PSE after adaptation, as compared to baseline.
PSE = point-of-subjective-equality.

underweight and overweight bodies (e.g., Ambroziak et al., 2019; Brooks et al., 2016; Hummel et al., 2012).

An ANOVA revealed a significant main effect of adapting body type, $F(1, 38) = 16.71$, $p < .001$, $\eta p^2 = .305$, with higher values in the overweight adaptation group than in the underweight adaptation group. Importantly, we also observed a significant interaction between the two factors, $F(1, 38) = 52.42$, $p < .001$, $\eta p^2 = .580$. Post-hoc comparisons with Holm–Bonferroni correction for multiple comparisons showed that this interaction was driven by a difference between conditions following adaptation, $t(38) = 6.37$, $p < .001$, $d = 2.013$, but no difference at baseline, $t(38) = 0.22$, $p = .83$, $d = 0.070$. As expected, no significant main effect of adaptation (i.e., baseline vs. adaptation) was observed because of the contrastive aftereffects in the two adaptation groups which canceled out the effect of adaptation, $F(1, 38) = 0.30$, $p = .59$, $\eta p^2 = .008$.

These results provide clear evidence for adaptation aftereffects of body size following haptic exploration. As discussed in the Introduction, numerous recent studies have demonstrated aftereffects following visual adaptation to extreme body shapes. This experiment extends these results to haptics.

Experiment 2

The haptic adaptation aftereffects reported in Experiment 1 are qualitatively similar to those found in several previous studies of visual adaptation aftereffects from underweight and overweight bodies (e.g., Ambroziak et al., 2019; Brooks et al., 2016; Hummel et al., 2012). There are, however, a range of differences between each of these studies and Experiment 1, which makes it difficult to quantitatively compare the magnitude of aftereffects following visual and haptic adaptation. We therefore conducted a second experiment using visual stimuli based on the same 3D modules used to create the haptic stimuli in Experiment 1 and using similar procedures.

Method

Participants. An additional 40 women participated in Experiment 2, 20 in each of the two adapting body type groups. This sample size was chosen to be consistent with Experiment 1. Note in addition, that the effect size calculated for Experiment 1 was based on data obtained in a previous study (Ambroziak et al., 2019), using visual body stimuli similar to that employed in Experiment 2. Participants in the *underweight adaptation* group were on average 28.8 years old (SD: 9.3) and all were right-handed (*M*: 83.5, *SD*: 20.1). Participants in the *overweight adaptation* group were on average 26.4 years old (SD: 7.3), and all but one were right-handed (*M*: 73.7, *SD*: 44.2).

Stimuli. In this experiment, we used visual stimuli created for our previous study (Ambroziak et al., 2019). The stimuli were 89 images of female bodies on a black background facing straight ahead. The height of each image was approximately 667 pixels (18 cm; placed in the middle of the 1074×882 image, 20.4° visual angle). The BMIs of female stimuli ranged from 13 (underweight) to 35 (overweight), in increments of 0.25 BMI units between each stimulus (see Figure 1, bottom panel). Note that there were a larger number of stimuli in the visual experiment compared to the haptic experiment. This was due to the practical advantage of creation and presentation of the visual stimuli over the haptic ones.

Procedures. The experimental design was similar to the first experiment, but instead of haptic stimuli, we used visual images of female bodies based on the same underlying 3D models used to create the figures in Experiment 1 and which we also used in our previous study (Ambroziak et al., 2019). Participants were seated in front of a 24-inch monitor (resolution: $1{,}600 \times 1{,}200$ pixels, refresh rate: 75 Hz), with eyes away approximately 56 cm from the screen. In the baseline condition, an image of a female body appeared on the screen for 0.5 s and participants made a verbal judgment of whether the body that they saw was fatter or thinner than an average female body of their age. To match the response mode to Experiment 1, participants responded again verbally and the experimenter entered their responses into the computer. In the adaptation condition, before starting the task, participants were adapted to images of underweight or overweight female bodies for 60 s. On each trial, after a 6-s "top-up" adaptation, they saw a test image for 0.5 s and indicated their answer to the experimenter. The prior estimates used for the "ascending" and "descending" staircases were 18 and 30, respectively.

Analysis. The main analyses were the same as in Experiment 1.

In addition, we performed further analyses comparing results in the haptic and visual modalities. We first compared judgments of body normality between haptics and vision in the baseline, before any adaptation, using a two-sample *t*-test. We next quantified the magnitude of adaptation as the difference in BMI between the body judged as most normal after adaptation compared to baseline. We analyzed this data using a two-way ANOVA with factors modality (haptic, visual) and adapting body type (underweight, overweight).

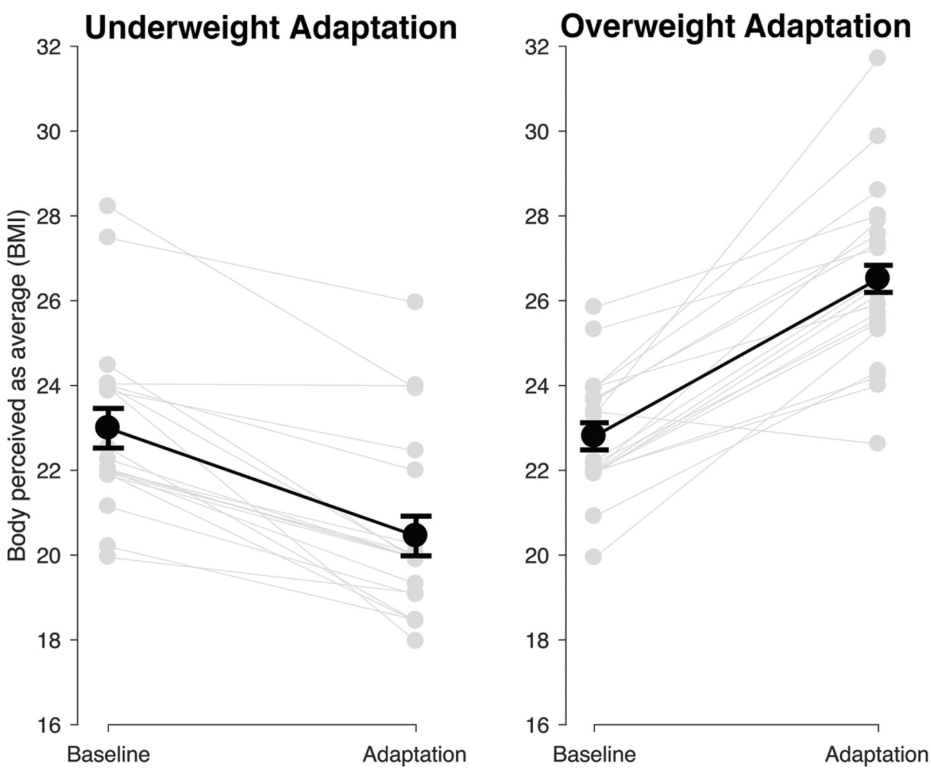

Figure 3. Results for underweight and overweight adaptation in the visual modality. The gray lines indicate individual participants, and the means are shown in black. *Left panel:* there was an effect of adaptation in the underweight adaptation condition, the PSE after adaptation significantly decreased, as compared to baseline, which indicates that participants judged subsequent bodies as fatter than during baseline. *Right panel:* there was an effect of adaptation in the overweight adaptation condition: there was a significant increase in PSE after adaptation, as compared to baseline.
PSE = point-of-subjective-equality.

Results

As in Experiment 1, there were clear aftereffects in both conditions, as shown in Figure 3. Following visual adaptation to an underweight body, participants judged subsequent bodies as more overweight as compared to baseline. This was observed by a shift of PSE in the direction of the adaptor. In particular, the mean perceived BMI decreased from 23.0 (*SD*: 2.1) to 20.5 (*SD*: 2.13), $t(19) = 7.92$, $p < .001$, $d_z = 1.771$. Following adaptation to an overweight body, the mean perceived BMI increased from 22.8 (*SD*: 1.4) to 26.5 (*SD*: 2.1), $t(19) = 8.62$, $p < .001$, $d_z = 1.928$, suggesting, that participants perceived following bodies as slimmer more often than before adaptation.

A 2 × 2 ANOVA revealed a significant main effect of adapting body type, $F(1, 38) = 27.44$, $p < .001$, $\eta_p^2 = .419$, which was modulated by a significant interaction between the adapting body type (underweight or overweight) and the adaptation condition (baseline vs adaptation), $F(1, 38) = 135.69$, $p < .001$, $\eta_p^2 = .781$. Post-hoc comparisons with Holm–Bonferroni correction showed that this interaction was driven by the conditions differing after adaptation, $t(38) = 9.03$, $p < .001$, $d = 2.85$, but not at baseline, $t(38) = 0.34$, $p = .736$, $d = 0.106$. In addition, a modestly significant main effect of adaptation, $F(1, 38) = 4.77$, $p = .035$, $\eta_p^2 = .112$ was observed.

Between-Experiment Comparisons

Because the haptic and visual stimuli were constructed using the same underlying 3D body models, we can ask whether there are any systematic differences between the perception of averageness in the two modalities. We thus compared the body perceived as most average in the baseline blocks of the two experiments. As the baseline block occurred before any adaptation, we collapsed across the underweight and overweight adaptation groups in each experiment. A 2-sample *t*-test revealed that the body perceived as most average was significantly larger for haptic stimuli (*M*: 25.0, *SD*: 1.9) than for visual stimuli (*M*: 22.9, *SD*: 1.8), $t(78) = 5.05$, $p < .001$, $d_z = 1.128$ (see Figure 4, left panel).

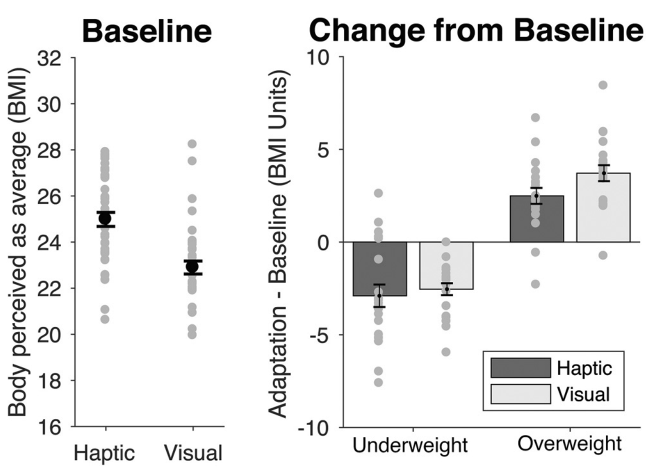

Figure 4. *Left panel:* comparison of haptic and visual perception across diverse body shapes relative to average. The body judged as average via touch was significantly larger than the body judged as average via vision. *Right panel:* Results showing aftereffect magnitude comparison between haptics and vision. There were no significant differences in the effects of adaptation to underweight and overweight bodies between the two modalities. Gray dots indicate individual participants and error bars represent standard errors in both panels.

We next compared the two modalities in terms of magnitude of adaptation, quantified as the difference in BMI following adaptation compared to baseline (see right panel of Figure 4). We then conducted a 2×2 between-subjects ANOVA with factors modality (haptic, visual) and adapting body type (underweight, overweight). There was a highly significant main effect of adapting body type, $F(1, 76) = 160.97$, $p < .001$, $\eta_p^2 = .679$, with changes in opposite directions for underweight versus overweight adaptors. This is consistent with the results already shown for each modality individually in Experiments 1 and 2, respectively. There was no significant main effect of modality, $F(1, 76) = 2.96$, $p = .089$, $\eta_p^2 = .038$, nor an interaction between modality and adaptation type, $F(1, 76) = 0.90$, $p = .347$, $\eta_p^2 = .012$. Thus aftereffects following adaptation to extreme body types are highly similar in both the haptic and visual modalities, both in terms of the basic nature of the effect and in terms of magnitude.

General Discussion

Exposure to extreme body types produces clear aftereffects in both haptics and vision. These effects are found for both underweight and overweight adapting bodies, and appear to operate similarly in the two modalities. These effects have been extensively researched in vision, and such visual adaptation to extreme bodies has been claimed to provide an experimental model of the established effects of media depiction of bodies on body image (Brooks et al., 2020). Our results extend this work to the haptic modality. This suggests that the effects of exposure to extreme body types are not a purely visual phenomenon, but reflect a broader representation of bodies. It is thus crucial to emphasize the role of haptics as a mechanism contributing to the creation of perceptual body image. Future research, such as exploring cross-modality effects between vision and haptics, could provide further insights into their impact on body perception.

One of the ways that girls from a young age gain their experience of what a "normal" body *feels* like through play with dolls. Consequently, our results have important implications for understanding the effects of playing with dolls on body perception. While our study focused on female body shape, the same point could clearly also be made about boys' experiences playing with dolls and action figures. Despite numerous studies have investigated the effects of playing with unrealistic dolls such as Barbie (Boothroyd et al., 2021; Jellinek et al., 2016; Worobey & Worobey, 2014), a little attention has been given to isolate haptic effects specifically. Indeed, some studies have investigated the effects of dolls entirely by having children look at, but not touch, the dolls (Dittmar et al., 2006; Worobey & Worobey, 2014). Also, when actual play with the dolls was included in the experimental paradigm, the participant's attention was directed more on the situational play with the dolls (e.g., acting the storyline, Rice et al., 2016), rather than concentrating on the effects of perceived adiposity of the viewed and touch bodies. It will be important for future research to try to isolate the visual, haptic, and multisensory contributions of playing with dolls to children's developing body representations.

A range of evidence from neuroimaging and patient studies has provided evidence that visual and haptic object recognition rely on at least partly overlapping neural mechanisms. Of particular relevance to this study, two studies (Costantini et al., 2011; Kitada et al., 2009) have shown that the extrastriate body area in the ventral visual pathway is activated by haptic exploration of body parts, complementing its well-established visual responsiveness to body parts (Downing et al., 2001). To our knowledge, however, this is the first study to investigate the perceptual processes involved in haptic perception of body size. The present results do, however, complement existing research on haptic perception of facial expressions. There is evidence that people can accurately recognize through haptic exploration of faces both personal identity (Casey & Newell, 2007; Dopjans et al., 2009; Kilgour & Lederman, 2002) and facial expressions of emotion (Lederman et al., 2007). Haptic face perception has also been found to show inversion effects as in vision (Kilgour & Lederman, 2006) and impaired in individuals with prosopagnosia (Kilgour et al., 2004). Moreover, aftereffects have been reported in this recognition following adaptation to specific emotions (Matsumiya, 2012, 2013).

A strength of the present study is that the same underlying 3D models of body shape were used to create both haptic and visual stimuli. This allowed us to match the stimuli in both modalities, to compare the nature and magnitude of adaptation aftereffects. There are, however, some important limitations of our study. Whereas visual stimuli had hair and were seen from a single frontal perspective, haptic exploration allowed participants to experience bold body stimuli from many angles. There is evidence, however, that vision and haptics show different sensitivities to viewpoints; while visual recognition is best from frontal views of objects, haptic recognition is best from the back (Newell et al., 2001). The frontal perspective used in Experiment 2 should therefore be optimal for vision, while the free exploration in Experiment 1 allowed participants to explore stimuli in an optimal manner, although the position of arms against the sides of the body in the haptic stimuli might have hindered proper exploration of the sides of the body figures. Moreover, even where the absolute duration of adaptation and exploration time is matched across modalities, the amount and nature of information obtained in haptics and vision is nearly impossible to quantify, let alone match between conditions. At some level, these simply reflect intrinsic differences between the haptic and visual modalities. These discrepancies in the adaptation protocols across modalities might influence the observed strength of adaptation aftereffects, which appeared similar across modalities in this study. Future research could explore this further to systematically investigate how specific modifications impact the magnitude and characteristics of aftereffects across different sensory modalities. Despite promising, these findings cannot be generalized to children or adolescents as well as men. The results were obtained mostly from young adult women with already-shaped body normality perceptions. Even though we did not set any restriction in terms of nationality or level of education, our sample is biased to female students from Europe and Asia, which are mostly studying in universities around central London. Further studies focusing on children, male and female with a broader nationality rage are therefore suggested.

In conclusion, we showed, for the first time using matched stimuli across visual and haptic modalities, analogous body shape aftereffects. These results may contribute to developing new paradigms in therapeutic work (e.g., targeting eating disorders) as well as designing new prevention programs addressing body disturbances in women. For instance, promoting satisfaction with one's body from a young age through play with various doll sizes and shapes as part of kindergarten learning may help women deal with body image pressures in future. Education can play a key role in this regard.

Author contribution(s)

Kasia A. Myga: Conceptualization; Data curation; Formal analysis; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing – original draft; Writing – review & editing.
Elena Azañón: Conceptualization; Formal analysis; Investigation; Methodology; Writing – review & editing.
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Annex 2: Supplementary material: Study 4
Annex 2a: Experiment 1a: autosuggestion

Question	N	Description*
Q1: Please describe below in your own words how did you autosuggest a happy face?	4	Used imagery.
	3	Changed their own mood according to autosuggested emotion to support autosuggestion outcomes, changed facial mimicry and made a story.
	7	Described areas of face analyzed but without giving exact strategies.
	1	Made unrelated comment.
	2	Superimposed autosuggested outcome on the image on the screen.
	2	Used verbal suggestions with imagery.
Q2: Please describe below in your own words how did you autosuggest a sad face?	2	Superimposed autosuggested outcome on the image on the screen (with additional techniques)
	8	Described areas of face analyzed and/or perceptual outcome but without giving exact strategies.
	1	Gave misinterpreted response.
	4	Used imagery.
	1	Referred to their own sad experiences.
	1	Used autosuggestion.
	1	Changed own emotion to feel sad.
Q3: Did you use pictures, imagery? (yes or no).	16	Yes.
	2	No.
Q4: If you used pictures, imagery, how did you do it? (e.g., did you imagine the person sad, happy? Did you impose your image on the picture? Did you imagine her in a situation?).	15	Used imagery (N = 4 created images in their head, N = 7 imagined her in a situation, N = 2 used imagery related to own experiences, and N = 2 superimposed imagined picture on the screen)
	3	Reported not using any images.
Q5: Were you smiling or changing your face when you were autosuggesting her being sad/happy?	15	Changed own facial expression for one or both conditions.
	1	Did not change own facial emotions.
	2	Changed mood but not always congruently with the autosuggested emotion.

Table S1. Summary of descriptions of how participants performed autosuggestion.

Annex 2b: Experiment 1b: autosuggestion

Question	N	Description*
Q1: Please write the specific phrases or statements you repeated in your head during the autosuggestion. If you did not repeat any statements respond: "I did not repeat any statement in my head"	19	Reported repeating sentences describing the facial emotion as happy or sad (e.g., "You look sad", "She looks very happy"), additionally n = 5 added personal scenarios to explain the perceived emotion, n = 1 reported modulating their own emotion to match the autosuggested emotion, n = 1 used autosuggestive sentences in their native language.
	1	Used imagery scenarios to place the person in a happy or sad context.
	1	Indicated that they used autosuggestion to evoke feelings of happiness or sadness in order to perceive the face as expressing those emotions.
	1	Did not repeat any statements.
Q2: Did you use any mental imagery or visualization techniques to assist with autosuggestion? If yes, please describe them. If no, respond: "I did not use any visualization or imagery."	8	Reported not using any imagery.
	13	Used imagery (n = 1 only in the sad condition)
	1	Provided a response that was unrelated to the question.
Q3: Did you mentally superimpose any imagined expression or mental image onto the face you were looking at to assist with autosuggestion? If yes, please describe how. If no, respond: "I did not superimpose any imagined image onto the face."	11	Did not superimpose any picture on the screen.
	2	Did not use imagery and thus did not superimpose the imagined picture on the screen.
	8	Superimposed the image on the screen.
	1	Provided a response that was unrelated to the question.
Q4: On this scale (1 to 5), please indicate how much you smiled or changed your facial expression, if at all, while autosuggesting the person as being sad or happy.	7	1 (not at all)
	2	2 (a little)
	4	3 (moderately)
	7	4 (quite a bit)
	2	5 (a great deal)

Q5: Did you use any additional techniques not previously mentioned? If yes, please describe them. If no, respond: "I have reported all the techniques I used."	17	Reported all techniques used.
	2	Focused on facial features.
	1	Reflected on personal emotional experience: found sadness easier to imagine due to personal experiences as a foreigner.
	1	Used auditory imagery for mood induction: imagined a song ("I'm Blue") to induce a sad mood.
	1	Judged the situation the person might be in to reinforce their initial impression.
Q6: On this scale (1 to 5), please indicate how much you relied on verbal suggestions vs mental imagery or other techniques during the task.	5	1 (entirely verbal suggestion)
	7	2 (mostly verbal suggestion)
	4	3 (equal reliance on both)
	5	4 (mostly mental imagery/other techniques)
	1	5 (entirely mental imagery/other techniques)
Q7: On this scale (1 to 5), please indicate how effective were you in autosuggesting that the face looked happy?	0	1 (not at all effective)
	8	2 (slightly effective)
	4	3 (moderately effective)
	6	4 (quite effective)
	2	5 (completely effective)
	2	Gave no answer.
Q8: On this scale (1 to 5), please indicate how effective were you in autosuggesting that the face looked sad?	0	1 (not at all effective)
	3	2 (slightly effective)
	6	3 (moderately effective)
	7	4 (quite effective)
	4	5 (completely effective)
	2	Gave no answer.

Table S2. Summary of descriptions of how participants performed autosuggestion.

Annex 2c: Experiment 2: imagery

Question	N	Description*
Q1: Please describe below in your own words how did you imagine a happy face?	5	Imagined own/other experiences of happiness.
	2	Imagined the person (n = 1 imagined her in a certain situation).
	3	Superimposed the imagined outcomes on the blurred image presented on the screen.
	1	Used auditory imagery to support their imagery outcomes (i.e., hearing the person laughing).
	2	Using auditory statements of imagined emotion.
	9	Did not disclose the process underlying their imagery outcomes.
Q2: Please describe below in your own words how did you imagine a sad face?	6	Referred to own or other experiences (N = 1 out of this group used auditory imagery to support their perceptual outcome (i.e., hearing the person sobbing).
	4	Superimposed the imagined imaged on the blurred outlie on the screen.
	1	Imagined the person while repeating the word 'sad' in their mind.
	7	Described the perceptual outcome of their imagery only.
	3	Interpreted the imagined emotion.
	1	Did not answer to this question.
Q3: If you used pictures, imagery, how did you do it? (e.g., did you imagine the person sad, happy? Did you impose your image on the picture? Did you imagine her in a situation?)	8	Placed the imagined person in a specific situation.
	5	Referred to their own experiences or those of people close to them (n = 1 participant did not complete their answer).
	5	Superimposed the imagined person on the blurred image on the screen.
	1	Created the images of the person outside of their head (i.e., being present in front of them).
	1	Changed their own mood according to the imagined emotion.
	2	Imagined how the person's eye areas and cheeks would move if they adapted the imagined expression.
Q4: Were you smiling or changing your face when you were imagining her being sad/happy?	13	Changed their mood according to imagined emotion.
	8	Did not change their mood.
	1	Changed the emotion sometimes, but never smiled.
Q5: Which face was easier for you to imagine? Sad or happy?	15	Happy.
	7	Sad.

Table S3. Summary of descriptions of how participants performed imagery.

Annex 2d: Experiment 3: emotional words

Question	N	Description*
Q1: Please write what you paid attention to when you looked at the long staying faces?	18	Looked mostly at the eyes and/or other parts of the face such as mouth, eyebrows, and forehead).
	1	Paid attention to the neutral expression of the face.
	1	Noticed that the faces were all the same and there was a word under each face describing the mood of the person in the image.
	1	Did not seem to understand the question.
Q2: Please describe what were you thinking when you were looking at the long staying faces on the screen.	13	Analyzed the emotional expression of the face in reference to the words written under (n = 6 did not find the correlation between observed face and the emotion word written, n = 2 tried to imagine this person in the situational context congruent with the emotion word, n = 2 tried to observe changes in her face, e.g. pupil dilation, but n = 1 did not succeed, n = 1 participant imagined the face as a scary 3-D shape).
	2	Paid attention to the facial features like location of eyes, mouth etc.
	2	Thought of different types of expressions or expressions for written emotion in one person.
	1	Expressed their boredom while looking at adaptors.
	1	Imagined the adaptor in real life and with real hair and final
	1	Tried to avoid thinking about the idea behind the experiment.
	1	Tried to remember how the adaptor looked like when the word described happy and sad emotion.
Q3: Did you pay attention to words under the faces?	19	Paid attention to words (in which N = 2 did it only at the beginning, and N = 1 only sometimes).
	2	Did not pay any attention to words.
Q4: Did the words on the screen affect your answers?	11	Were affected by the words, but did not provide details in which direction.
	8	Claimed that their answers remained unaffected by the words.
	1	Explained that they had the words in their mind all the time.
	1	Did not see any words.
Q5: Please make guess what we wanted you to answer on each trial?	11	Expected the words under the adaptors influencing their answers, (out of these, N = 1 detailed that one should respond ‘happy’ on the happy trials (i.e., happy condition) and ‘sad’ in the sad condition).
	1	Did not know what was expected.
	1	Thought that the answers should vary based on their own mood.
	4	Said that they should judge emotions in test faces.
	4	Did not seem to understand the question.
Q6: Which faces did you judge as happy/sad? The ones that were on the screen for longer or shorter period of time?	12	Judged the test faces.
	9	Did not seem to understand the question or gave responses not related to the question.

Table S4. Summary of follow-up questions in Experiment 3.

Annex 2e: Experiment 4: perception

Question	N	Description*
Q1: Did you always look at the face that stayed on the screen for longer period of time?	23	Yes.
Q2: What were you thinking when you were looking at the face for a long time?	14	Analyzed the emotion content in the adapting faces.
	2	Tried to observe or remember the details/features of the adapting faces.
	1	Tried to 'free their mind and just sharply look at the faces'.
	1	Perceived 'morphing' of the faces, without giving more details.
	1	Experienced confusion as to how many happy and sad faces there were.
	1	Analyzed their answers on previous trials.
	1	Was wondering whether they had seen this person before.
	1	Did not seem to understand the question.
	1	Experienced frustration with labelling the person as happy or sad and in the final phase they did not want to continue the task, but did not inform the experimenter about it.
Q3: Which faces did you judge as happy or sad? The faces that were on the screen for longer or shorter period of time? *	15	Judged test faces.
	3	Judged adaptors.
	5	Did not seem to understand the question.
Q4: Make a guess what we wanted you to answer on each trial?	4	Appeared to be aware of the contrastive effects of adaptation. **
	2	Made a guess in the direction of assimilative adaptation aftereffects.
	7	Indicated that the adaptor should influence their subsequent judgments, but didn't state the direction of those judgments.
	3	Were not aware of the experimental manipulation.
	1	Stated that the longer staying faces on the screen did not affect their judgements of the test faces.
	6	Did not seem to understand the question.

Table S5. Summary of follow-up questions in Experiment 4.
* Note that the 3 participants reporting judging the adaptors showed very clear contrastive aftereffects, it is thus probable that they misunderstood the question. Removal of these participants yields similar results: $t(19) = -11.751$, $p < .001$, $d_z = -2.628$.
** Removing these participants yields similar results, $t(18) = -11.490$, $p < .001$, $d_z = -2.363$.

Wording of the Declaration of Honour

“I hereby declare that I prepared this thesis without the impermissible help of third parties and that none other than the aids indicated have been used; all sources of information are clearly marked, including my own publications.

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Magdebrug, den 21. Januar 2025 Kasia Anna Myga

List of abbreviations

ABBA	A and B stand for two separate conditions in the experiment, ABBA indicates the order of the conditions
AT	autogenic training
BOLD	blood oxygen level-dependent
°C	Celsius
CIs	confidence intervals
cm	centimeter
CBT	cognitive behavior therapy intervention
EEG	electroencephalography
fMRI	functional magnetic resonance imaging
Hz	Herz
ISI	Interstimulus interval
ITI	Inter trial stimulus
JASP	Jeffrey's Amazing Statistics Program
JND	Just Noticeable Difference
LIN	Leibniz Institute for Neurobiology
max	maximum
min	minimum
MISS	Multidimensional Iowa Suggestibility Scale
ms	milliseconds
N/n	Number
OSF	Open Science Framework
p	p-value
PET	Positron Emission Tomography
PHR	Physiological Reactivity
PSC	Psychosomatic Control
PSE	Point of Subjective Equality
r	Wilcoxon effects size
R^2	coefficient of determination
RHI	Rubber Hand Illusion
rACC	rostral anterior Cingulate Cortex
s	second(s)
SC	Sensation Contagion
SD	Standard Deviation
SOA	Stimulus Onset Asynchrony
SPSS	Statistical Package for the Social Sciences software
SUIS	The Spontaneous Use of Imagery Scale
SSS	Short Suggestibility Scale
t	t-value, test statistic in t-test
TOJ	Temporal Order Judgement
V	Volt
vmPFC	ventromedial Prefrontal Cortex
VVIQ	The Vividness of Visual Imagery Questionnaire
z	standardized test statistic in a Wilcoxon test

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List of publications

1. **Myga, K. A.**, Longo, M. R., Kuehn, E., Azañón (2025). Autosuggestion and Mental Imagery Bias the Perception of Social Emotions. bioRxiv. https://doi.org/10.1101/2025.01.09.632121

2. **Myga, K. A.**, Kuehn, E., & Azañón, E. (2024). How the inner repetition of a desired perception changes actual tactile perception. Scientific Reports, 14(1), 3072. https://doi.org/10.1038/s41598-024-53449-7

3. **Myga, K. A.**, Azañón, E., Ambroziak, K. B., Ferrè, E. R., & Longo, M. R. (2024). Haptic experience of bodies alters body perception. Perception, 53(10), 1-14. https://doi.org/10.1177/03010066241270627

4. **Myga, K. A.**, Kuehn, E., & Azanon, E. (2022). Autosuggestion: a cognitive process that empowers your brain? Experimental Brain Research, 240(2), 381-394. https://doi.org/10.1007/s00221-021-06265-8

5. **Myga, K. A.**, Ambroziak, K. B., Tamè, L., Farnè, A., & Longo, M. R. (2021). Whole-hand perceptual maps of joint location. Experimental Brain Research, 239, 1235-1246. https://doi.org/10.1007/s00221-021-06043-6

Conference contributions

- **Myga, K. A.**, Tsiagka, S., Kuehn, E., Longo M. R., & Azañón, E. (2024). Adaptation aftereffects: reshaping perceptions and enhancing mental health. Poster presented at the event: "PsychCircuits - Building Bridges for Mental Health" Magdeburg, Germany

- **Myga, K. A.**, Longo M. R., Kuehn, E., & Azañón, E. (2024). The modulatory effects of autosuggestion on perception. Poster presented at the 14th Symposium of Bial Foundation, Porto, Portugal

- **Keynote speaker** on the seminar series Science of Suggestion. https://scisugg.wordpress.com (2022)

- **Myga, K. A.**, Kuehn, E., & Azañón, E. (2022). Changing tactile amplitude and frequency perception via autosuggestion. Poster presented at the 20th Multisensory Research Forum, Ulm, Germany

- **Myga, K. A.**, Kuehn, E., & Azañón, E. (2022). Changing tactile amplitude and frequency perception via autosuggestion. Poster presented at the 9th MindBrainBody Symposium (MBB), Berlin, Germany

- **Myga, K. A.**, Ambroziak, K. B., Ferré, E. R., Azañón, E., Longo M. R. (2019). Exploring haptic body perception. Poster presented at the Experimental Psychology Society (EPS) Summer Meeting, Bournemouth, England