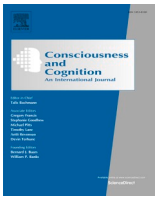
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Review article



How hypnotic suggestions work – A systematic review of prominent theories of hypnosis

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ABSTRACT

In recent decades, hypnosis has increasingly moved into the mainstream of scientific inquiry. Hypnotic suggestions are frequently implemented in behavioral, neurocognitive, and clinical investigations and interventions. Despite abundant reports about the effectiveness of suggestions in altering behavior, perception, cognition, and agency, no consensus exists regarding the mechanisms driving these changes. This article reviews competing theoretical accounts that address the genesis of subjective, behavioral, and neurophysiological responses to hypnotic suggestions. We systematically analyze the broad landscape of hypnosis theories that best represent our estimation of the current status and future avenues of scientific thinking. We start with procedural descriptions of hypnosis, suggestions, and hypnotizability, followed by a comparative analysis of systematically selected theories. Considering that prominent theoretical perspectives emphasize different aspects of hypnosis, our review reveals that each perspective possesses salient strengths, limitations, and heuristic values. We highlight the necessity of revisiting extant theories and formulating novel evidence-based accounts of hypnosis.

1. Introduction

Hypnosis has achieved recognition in the scientific community as a topic that warrants intensive investigation and has documented value in clinical and research settings. Hypnosis is increasingly employed in clinical settings to attain a variety of objectives, including treating depression (e.g., Alladin & Alibhai, 2007), anxiety-related disorders (e.g., Valentine et al., 2019), acute and chronic pain (Thompson et al., 2019), obesity and excessive weight (Kirsch, 1996; Milling et al., 2018), and irritable bowel syndrome (Schaefert et al., 2014; Tan et al., 2005), as well as enhancing self-acceptance (e.g., Milburn, 2010) and as an adjunct to cognitive-behavior therapy (e.g., Schoenberger, 2000). In basic research, hypnotic and posthypnotic suggestions are frequently employed to investigate psychological functions and their neurocognitive mechanisms, such as inhibition (e.g., Iani et al., 2006; Raz et al., 2006; Zahedi

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[1] Unfortunately, our great friend and co-author, Steven Jay Lynn, passed away during the revision of the current paper. However, as he had an immense effect on this contribution and our thinking about hypnosis in general, we decided to maintain him as a co-author on the paper. May this serve as a tribute to his memory.

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et al., 2019), working memory (e.g., Lindelov et al., 2017; Zahedi et al., 2020b), perception (e.g., Derbyshire et al., 2004; McGeown et al., 2012; Perri et al., 2019), and implicit motivation (e.g., Ludwig et al., 2014; Zahedi et al., 2020a). Today, hypnotic phenomena, including but not restricted to hallucinations, pain insensitivity, amnesia, and alterations in the experience of agency, are actively studied on an international basis.

Although hypnosis can boast increasingly well-established efficacy and applicability, no consensus exists regarding the mechanisms of hypnosis and hypnotic suggestions. Important questions at the vanguard of research and theoretical inquiries include the following: What mediates and moderates diverse phenomena subsumed under the name hypnosis? What accounts for the effectiveness of hypnosis in modifying such disparate functions as behavior, perception, cognition, and the subjective sense of agency? These and similar theoretical questions have arguably not been addressed systematically since Sheehan and Perry's (1976) volume, *Methodologies of Hypnosis*, and later Lynn and Rhue's (1991) volume, *Theories of Hypnosis*. Notably, although there are several other vital contributions, such as The Oxford Handbook of Hypnosis: Theory, Research, and Practice., 2008, these volumes focus more broadly on theoretical, experimental, methodological, and clinical aspects rather than a systematic analysis of existing theories of hypnosis.

The theoretical landscape has changed remarkably over the years and warrants in-depth and critical analysis. Hence, we systematically review competing theoretical accounts that address questions regarding the genesis of subjective, behavioral, neural, and psychophysiological responses to hypnotic suggestions. The selected theories (for selection criteria, see Section 2) represent the broad terrain of influential, generative, and research-based contemporary hypnosis theories. These theories best represent our assessment of the current status and future avenues of scientific thinking about hypnosis. Prominent theoretical perspectives emphasize different aspects of hypnosis, and each possesses salient strengths, limitations, and heuristic values. Although our review represents only one construal of the theories we survey, our overview can foment meaningful dialogue that spurs advancements in conceptualizing, researching, and applying hypnosis clinically. Theory and research regarding hypnosis are also relevant to many domains of psychological science and clinical practice beyond the more delimited arena of hypnosis. Accordingly, we hope our analysis intrigues and motivates scientists and clinicians who are not already familiar with hypnosis to pursue their curiosity and contribute to the burgeoning literature we review. We first describe the procedural aspects of hypnosis, introduce common hypnotic phenomena, and then discuss individual differences in responsiveness to hypnotic suggestions before we consider each theory in turn.

1.1. Hypnosis

The hypnosis procedure commonly consists of three often overlapping stages (Hammond, 1998; Kihlstrom, 2008): induction (orienting or disorienting), an intermediary phase consisting of suggestions, and termination (i.e., de-induction). All three stages consist of direct verbal suggestions and are induced by another person, called or perceived as the hypnotist, who presents suitable suggestions (Kihlstrom, 1985; Lynn et al., 2015a; Lynn et al., 2015b). Direct verbal suggestions used during hypnosis commonly aim to create a suggested reality that might contradict the actual reality as it is experienced and known (Oakley et al., 2021; Polczyk, 2016).

For inducing hypnosis, numerous suggestions can be used (Hammond, 1998), but most inductions share two basic aims. First, inductions typically aim to establish positive expectancies about the procedure (e.g., defining the context as "hypnotic") that are geared to increase hypnotic responsiveness (Braffman & Kirsch, 1999). For instance, the word "hypnosis" is intended to cue participants that the current situation may differ vastly from mundane conditions and enhance responsiveness to suggestions (Gandhi & Oakley, 2005). Second, inductions typically aim to attract participants' attention, increase absorption in inner experiences and hypnotic suggestions, and consolidate hypnosis-related expectancies (Brown et al., 2001). Although induction is commonly associated with relaxation suggestions (Edmonston, 1977, 1991), it can also be induced during strenuous physical activity (Banyai & Hilgard, 1976; Malott, 1984).

After the induction phase, hypnotic and posthypnotic suggestions are presented, typically directed toward a targeted change in overt behavior, perception, or cognition. Finally, a suggestion will commonly cue the termination of hypnosis, direct attention to the physical surroundings, and reestablish normal expectancies about the impact of one's behavior and perception of external stimuli (Hammond, 1998; Shor & Orne, 1962).

According to Kihlstrom (2008), the domain of hypnosis consists of responses to particular types of suggestions – suggestions for alterations in overt behavior, perception, cognition, memory, and the voluntary control of behavior – in hypnotized participants. Thus, the domain of hypnosis incorporates, first, objective and measurable changes in overt behavior, perception, and cognition and, second, alterations in the subjective sense of agency (SoA) or the sense of conviction. In the two following sections, we will briefly review the objective and subjective effects of suggestions.

1.2. Objective changes in overt behavior, perception, and cognition

Most commonly, hypnotic and posthypnotic suggestions *trigger well-learned or well-known responses.* Suggestions that result in physical movements are commonly divided into direct- and challenge-ideomotor suggestions (e.g., McConkey et al., 1980; Woody et al., 2005). These names refer to the concepts that Eysenck (1943) and Eysenck and Furneaux (1945) introduced. Direct-ideomotor items trigger a movement when there is no contradictory sensory information by suggesting that participants think of (I) that movement or (II) a well-known stimulus and its effects that usually lead to or produce that movement. For example, one of the direct-ideomotor items of the Harvard Group Scale of Hypnotic Susceptibility – form A (HGSHS-A) suggests "think of your head falling forward … and you feel a tendency to make the movement" (Shor & Orne, 1962, p. 4). Another HGSHS-A item, which focuses on a well-known stimulus and its effects, suggests: "your hand starts to feel heavy… imagine that a weight is pulling it down… as it feels heavy, it begins to move" (Shor & Orne, 1962, p. 7). Several studies using the item-response theory indicate that participants respond to direct-

ideomotor suggestions more often than other types of suggestions (McConkey et al., 1980; Näring et al., 2004). Challenge-ideomotor items aim to inhibit a motor response despite a secondary suggestion to resist or overcome the primary one. For example, in the arm-immobilization suggestion, it is stated that "your hand feels heavy… too heavy to be lifted. Why don't you see how heavy it is. Just try to lift your hand up" (Shor & Orne, 1962, p. 5). Evidently, in the arm-immobilization suggestion, the instruction to lift the hand contradicts the suggested sensation of heaviness.

Suggestion-triggered responses can also be physiological and somatic reactions induced by imagining a typically well-known stimulus. Notably, imagination here refers to not only visual but also auditory, tactile, gustatory, or olfactory mental imagery. When participants are asked to imagine the sourness of a lemon, they are encouraged to engage in gustatory imagery, which usually leads to saliva secretion (Hammond, 1990, 1998). Induced responses may also be a change in perception without any overt action. In the hypnosis nomenclature, changes in perception are commonly designated as hallucinations. Positive hallucinations denote perceiving previously encountered stimuli in their absence, and negative hallucinations refer to the complete, partial, or temporary agnosia of stimuli that are present. A typical positive hallucination is a color hallucination, such as seeing a grayscale in different colors when suggested to do so (Mazzoni et al., 2009; McGeown et al., 2012). A widely used negative hallucination is the hypnosis-induced elimination or reduction of pain inflicted by noxious stimuli (e.g., Perri et al., 2020b; Perri et al., 2019; for review, see Thompson et al., 2019). Responses can be characterized as objective when changes in perceptions can be measured objectively, for instance, by implicit tasks or alterations in psychophysiological responses.

Hypnotic and posthypnotic suggestions can also affect cognitive functions. Suggestions can *modify* responses to external stimuli, *substitute* habitual responses with more appropriate ones, *enhance* adaptive cognitive functioning, or *facilitate* learning novel responses (for review, see Lifshitz et al., 2013). These cognitive functions are considered top-down processes. Therefore, their modulations by hypnotic and posthypnotic suggestions signal the relevance of hypnosis to top-down processing in general (Terhune et al., 2017).

Executive functions provide a canonical example of cognitive processing (Baddeley, 2003; Diamond, 2013). Even though researchers have proposed different taxonomies (Diamond, 2013; Miyake et al., 2000), two executive functions are considered pivotal. The first function, updating (sometimes called working memory), entails storing, retrieving, and substituting information in working memory buffers, whereas the second, inhibition, refers to suppressing prepotent but task-inappropriate actions (Diamond, 2013; Miyake et al., 2000). Many studies have shown that task-relevant hypnotic and posthypnotic suggestions enhance performance in both inhibition (e.g., Iani et al., 2006; Perri et al., 2020a; Raz et al., 2006; Zahedi et al., 2019) and updating tasks (e.g., Lindelov et al., 2017; Zahedi et al., 2020b).

Nevertheless, some studies found that hypnosis without task-relevant suggestions (sometimes referred to as neutral hypnosis) may negatively affect performance in tasks that challenge executive functions (Sheehan et al., 1988). However, other studies employing neutral hypnosis found no effect on cognitive functioning (Egner et al., 2005; Zahedi et al., 2017) or even improvements, for example, in implicit serial reaction-time tasks (Nemeth et al., 2013).

Finally, hypnotic and posthypnotic suggestions can affect long-term memory (Kihlstrom, 2014). For example, posthypnotic suggestions have been used to induce amnesia (e.g., Kihlstrom, 1980). Notably, posthypnotic amnesia does not affect stored information (i.e., semantic memory) but knowledge about when, where, and how it had been acquired (i.e., episodic memory). These findings lend credibility to claims that posthypnotic amnesia is related to source amnesia and pertains to modulations of explicit but not implicit memory (Barnier et al., 2001; Bryant et al., 1999; David et al., 2000).

1.3. Alterations in the subjective sense of agency (SoA)

Numerous reviews and theoretical treatises focusing on hypnosis put alterations in SoA at the forefront of their discussions (e.g., Hilgard, 1973; Kihlstrom, 2008; Lynn et al., 2015b; Martin & Pacherie, 2019; Terhune et al., 2017). This emphasis is due to the prevalence of participants reporting a sense of semi-automaticity, effortlessness, and involuntariness when they exhibit hypnotic-suggestion-induced responses (Blakemore et al., 2003; Kirsch & Lynn, 1997; Lynn et al., 1990). However, the experience of involuntariness does not imply a loss of control over responses. If appropriately encouraged, participants can resist induced responses (Lynn et al., 1984; Spanos et al., 1985). Further, induced responses are not automatic in that they are resource-consuming (e.g., Tobis & Kihlstrom, 2010); however, for contradictory results, see Miller and Bowers (1993). A closely related construct to SoA is the sense of reality (SoR), which is how a person's self is defined based on the history of personal interaction with others, with one's body, and one's relevant social and physical environment (Straus, 1978). Hypnosis not only affects participants' SoA, but it might also affect how they perceive their surroundings and themselves in that environment (Kihlstrom, 2008).

SoA is not an unimodal construct itself, as Polito et al. (2013) showed that at least two factors can be separated: effortlessness and involuntariness. Although involuntariness is stable, effortlessness might be more volatile and dependent on other antecedents (Polito et al., 2013). Alterations in SoA (and related constructs such as SoR) are not confined to hypnotic experience but can be observed similarly during meditation and under the influence of psychedelics (Timmermann et al., 2023) or in diseases such as schizophrenia (Polito et al., 2015).

Positive responses to hypnotic and posthypnotic suggestions are highly, but not perfectly, correlated with the experience of involuntariness (Bowers et al., 1988; Polito et al., 2013). Furthermore, the subjective sense of conviction, probably based on altered SoR, is essential for separating hypnotic from non-hypnotic suggestions (Spanos & Barber, 1968). Therefore, any successful theory must be capable of explaining alterations in SoA and SoR.

1.4. Hypnotizability

Participants differ in their responsiveness to hypnotic and posthypnotic suggestions (Hilgard, 1965b; McConkey et al., 1980; Woody et al., 2005; Zahedi & Sommer, 2022). Hypnotic responsiveness can be operationally defined as what standardized hypnosis scales measure (for review, see Woody & Barnier, 2008). Most scales consist of an induction procedure, commonly by suggestions for relaxation and/or concentration, followed by test suggestions, differing in difficulty. Subjective or objective responses to these suggestions are then used to measure hypnotic responsiveness (Woody & Barnier, 2008), conventionally defined in terms of the number of passed suggestions on a standardized scale. As an example, consider HGSHS-A, which consists of 12 items (Shor & Orne, 1962). In HGSHS-A, participants with scores ≥ 9, $8 \geq$ scores ≥ 5, and $4 \geq$ scores are considered high-, medium-, and low-hypnotic-responsive, respectively. Based on different norms (e.g., Anllo et al., 2017; Bongartz, 1985; De Pascalis et al., 2000; Shor & Orne, 1963), approximately 15–20 percent of participants are high-, 60–70 percent medium-, and 15–20 percent low-hypnotizable. Notably, hypnotic responsiveness measured by these tests is stable within subjects with $stability\ coefficient(15-year\ retest) = 0.82; stability\ coefficient(25-year\ retest) = .71$ (Piccione et al., 1989). However, in the cross-sectional studies (Morgan & Hilgard, 1973), it is shown that participants in the age interval 9–12 years are more hypnotizable than other age groups, and there is a gradual decline thereafter.

Can hypnotic responsiveness be defined theoretically, i.e., independent of the standardized scales? Based on studies that Eysenck (1943) and Eysenck and Furneaux (1945) conducted, two forms of suggestibility can be distinguished: primary versus secondary. Primary suggestibility, also called direct verbal suggestibility (Oakley et al., 2021; Polczyk, 2016) and imaginative suggestibility (Braffman & Kirsch, 1999), is focused on direct, overt suggestions, whereas secondary suggestibility targets indirect suggestions. Although it is commonly accepted that hypnotizability is related to direct verbal suggestibility, they cannot be equated (Oakley et al., 2021; Polczyk, 2016). To theoretically define hypnotizability, Kirsch (1997) distinguished between (I) direct verbal suggestibility, as the capability to respond to suggestions outside of hypnosis (called non-hypnotic suggestibility); (II) hypnotic suggestibility as the capability to respond to suggestions provided during hypnosis or post-hypnotically; and (III) hypnotizability as the increase in suggestibility due to the induction of hypnosis (i.e., the difference between hypnotic and non-hypnotic suggestibility). According to Kirsch (1997), common hypnosis scales measure hypnotic suggestibility rather than hypnotizability per se. Notably, non-hypnotic and hypnotic suggestibility are correlated strongly ($r = 0.67$ behavioral scores; $r = 0.82$ subjective scores; Braffman & Kirsch, 1999). Therefore, measuring hypnotizability, as Kirsch (1997) defined it (i.e., ascertaining a difference between the two types of suggestibility), can be challenging.

In his seminal work, Hilgard (1965a, 1965b) introduced the idea that responding to suggestions might be factorially complex and depend on two "necessary but not sufficient" variables: general hypnotizability and specific cognitive processes required for responding to different groups of suggestions. He categorized suggestions based on their contents into six groups: agnosia and cognitive distortion, positive hallucinations, negative hallucinations, dreams and regressions, amnesia and posthypnotic suggestion, and finally, loss of motor control (Hilgard, 1965a, 1965b). Confirming this hypothesis, many studies (e.g., Hilgard, 1965a, 1965b; McConkey et al., 1980; Woody et al., 2005; Zahedi & Sommer, 2022) have shown that hypnotic suggestibility, as measured by standardized scales, is composed of several abilities. However, these studies consistently indicate a maximum of four categories, which are not ordered content-wise, as Hilgard (1965b) suggested, but function-wise (i.e., direct- versus challenge-ideomotor suggestions). In other words, the heterogeneity in responding to different hypnotic and posthypnotic suggestions cannot be attributed simply to item difficulty (Acunzo & Terhune, 2021; Reshetnikov & Terhune, 2022; Zahedi & Sommer, 2022). Although item difficulty might be a contributor along with other factors, it cannot alone explain individual differences in responding to suggestions (McConkey et al., 1980). Whereas standardized measures do not measure a unitary ability, the number and nature of the measured abilities have proven to be elusive (for review, see Lynn et al., 2019). Recently, Zahedi and Sommer (2022) showed that HGSHS-A scores are better explained by a bifactorial structure, which aligns with both Hilgard's proposition and Kirsch's theoretical definition of hypnotizability.

Both psychosocial and cognitive factors affect responses to hypnotic and posthypnotic suggestions. Psychosocial factors, such as participants' willingness and openness (Green & Lynn, 2011; Lynn et al., 2015b), prior expectations about hypnosis (Kirsch & Lynn, 1997), rapport with the hypnotist (Lynn et al., 2019), and motivation to respond to suggestions (Jones & Spanos, 1982) are important determinants of hypnotic suggestibility. However, the relation between cognitive capabilities and hypnotic responsiveness is more complex. Although some recent neurocognitive studies reported that hypnotic suggestibility is positively correlated with cognitive task performance (Faerman & Spiegel, 2021; Kirenskaya et al., 2019; Srzich et al., 2019), others found no meaningful or even negative correlations (Dienes et al., 2009; Khodaverdi-Khani & Laurence, 2016). Terhune et al. (2011) suggest that dissociative tendencies [i.e., a mild form of disruption in integrating thoughts, feelings, and experiences in the stream of consciousness (Kihlstrom et al., 1994)] might moderate the relation between cognitive capabilities and hypnotic suggestibility. That is, individuals with high compared to low dissociative tendencies would rely less on cognitive capabilities to respond to suggestions (King & Council, 1998; Terhune, 2015; Terhune & Cardeña, 2010; Terhune et al., 2011).

Beside standardized tests of hypnotizability, which primarily focus on objective responses to suggestions, other adjunct measures, such as experiential analysis of hypnosis (EAT; Sheehan et al., 1978), or separate questionnaires, such as phenomenology of consciousness inventory (PCI; Pekala & Kumar, 2007) and more recently sense of agency rating scale (SOARS; Polito et al., 2013), focus on subjective responses more specifically. The results of these tests further indicate that the hypnotized person is a cognitively active participant who uses various skills and strategies to respond to suggestions. Accordingly, studies have found at least two different groups of high-hypnotizable participants (Terhune, 2015; Terhune & Cardeña, 2010; Terhune et al., 2011). However, these categorical differences cannot explain the dimensional characteristics of the hypnotizability scores discussed above (Reshetnikov & Terhune, 2022). Consequently, any successful theoretical explanation should be able to justify the observed intra- (i.e., dimensional) and inter-

individual (i.e., typological) differences in hypnotizability. Theories should also advance a falsifiable and testable structure that explains hypnotizability and its subcomponents.

2. Selection procedure and review of prominent theories

To systematically identify pertinent theories for review, we searched the electronic databases Google Scholar, Scopus, and Web of Science using the keywords *Hypnosis* and at least one of the following: *Model*, *Synthesis*, *Framework*, *Theory*, and *Perspective* (see supplementary materials Fig. S1). Publications that had at least 20 citations (n = 176; November 2022) were considered further. After eliminating duplicate publications (n = 115), the remaining reports were screened to determine whether they proposed a hypnosis theory. This procedure eliminated 42 articles due to not being eligible. Out of the remaining 73 manuscripts, 25 distinguishable theories could be identified, which we classified into 10 categories. If we identified several iterations of one theory, we tried to combine them and present them as a single theory, and in case of any contradictions or vagueness, we relied on the most recent version. Given the large number of hypnosis theories, our screening generally served to ensure that our coverage of theories was reasonably comprehensive and consistent with the attention theories have attracted in the scientific community. However, we were selective in adjusting those theories we deemed least derivative and overlapping with other theories, most generative and heuristic in nature, and consistent with developments in contemporary psychological science. That said, we are confident that our review represents the most expansive and detailed evaluation of theories to date.

Based on criteria outlined by philosophers of science, such as Karl Popper (1971), any theory has two general purposes. First, it attempts to offer an unbiased summary of the existing data (Popper, 1971). This summary should (I) account for as many phenomena as possible without contradiction (i.e., adequacy) and (II) ceteris paribus, make fewer assumptions (i.e., parsimony). However, the domain of hypnosis is so vast (Kihlstrom, 2008; Kihlstrom, 2014; Lynn et al., 2019) that the adequacy of a corresponding theory appears to be more vital than its parsimony (Jensen et al., 2015).

We will first describe each theory and address which phenomena a given theory aims to explain. Further, we will ask whether a theory is limited to the psychological level or also discusses neural aspects of the phenomena. Not every theory attempts to address all of the mentioned points. Accordingly, for each theory, we will only discuss the hypnotic phenomena that theorists attempt to explain and the outcomes of key empirical tests of predictions derived from the theory. However, a theory might be modified and/or expanded, enabling it to explain other phenomena in the domain of hypnosis beyond its initial explicit formulation. Notably, regarding some phenomena, such as hypnotizability, it is possible for different theories to focus on and explain different aspects of it. Regarding hypnotizability, this is conspicuous when one notices that previous studies (e.g., Woody et al., 2005; Zahedi & Sommer, 2022) have shown the structure of hypnotizability might be understood differently based on the theoretical stances a model takes. In other words, although it is common knowledge that hypnotizability has a multifactorial structure, the nature and number of the factors are disputed.

Notably, after introducing the basic concepts of each theory, we critically evaluate the congruency of each theory with the existing results and observations. In doing so, at many points, we needed to use postulations and assumptions of the theories to determine their stance on certain questions. This interpretative step, however, should be considered as reflecting our understanding of the theories rather than as the only possible interpretation. We highlight these sections in regard to each theory by explicitly labeling them as evaluative rather than descriptive.

The selected theories (Table 1) are discussed roughly chronologically; however, in some places, the historical organization is violated as some theories are critical for comprehending others.

2.1. Psychoanalytic theories of hypnosis

We begin with clinical, psychoanalytic theories since they are among the first attempts at understanding hypnotic phenomena. Although different psychoanalytic theories might rely on vastly different mechanisms to explain hypnotic phenomena, they rely on some basic shared assumptions. Two such assumptions are the hierarchical structure of consciousness and hypnosis as an altered state of consciousness (Gill & Brenman, 1959). The hierarchical structure of consciousness refers to Freud's distinction between conscious and unconscious processes (Grossman, 1992). In his seminal work, Freud depicts a pyramid where conscious processes, carried out predominantly by the ego, are a small proportion of the agent's mentation. The vast majority of mental life, however, is either preconscious or unconscious matters. Preconscious matters can become conscious but are not required or relevant at the moment (Fromm, 1976). On the other hand, unconscious ones will face resistance to becoming conscious due to their anxiety-provoking properties (Fromm, 1976).

This hierarchical system not only divides the content between different subcomponents but also distinguishes the mode and range of cognitive processing and attributes a second property to the unconscious life: being primitive and governed by primary processes. These primary processes are contrasted with reality-oriented mentation, called the secondary process, which dominates conscious mentation (Fromm, 1976; Nash, 2008). Any technique that causes a change from secondary to primary cognitive processes (or vice versa) induces an altered state of consciousness by definition.

Aligned with these two principles and heavily relying on Gill and Brenman (1959), Nash (1992, 2008) introduced a psychoanalytical theory of hypnosis. Nash (1992, 2008) postulates that (1) the topographical regression during hypnosis, i.e., adaptive regression in service of the ego from secondary to primary-process thinking, is the basis of hypnotic phenomena. (2) The transient and revocable altered state of consciousness characterized by the primary process can explain the effects of neutral hypnosis (Gill & Brenman, 1959). The psychoanalytical theory of hypnosis posits a relation between hypnosis and more spontaneous and intense emotions, unusual body sensations, the experience of non-volition, and the tendency to transfer the core attributes of significant others onto the hypnotist

(Nash, 1992, 2008; Nash & Spinler, 1989). However, Lynn and Kirsch (2006) noted that although researchers have found evidence of primary processes during hypnosis, including unusual perceptual and bodily experiences and high rapport with the experimenter (Nash & Spinler, 1989), such responses are not specific to hypnosis. Considering these two critical shared assumptions of psychoanalytic approaches, we will now discuss a more nuanced version separately.

2.1.1. Ego-Psychological theory of hypnosis

In her "ego-psychological theory of hypnosis," Erika Fromm (1992) proposes two original concepts for explaining hypnotic phenomena. The first concept is ego-receptivity, which is contrasted to ego-activity and −passivity. The ego is active when there is a choice to be made, whereas ego-passivity refers to situations when this autonomy is lost with regard to "the stimuli [that the agent] receives from [their] instinctual drives, the environment, or the superego" (Fromm, 1976, p. 559). However, in many situations where voluntarism is relinquished, the ego is receptive rather than passive. In other words, ego-receptivity comes into play when "critical judgment, adherence to reality orientation, and active goal-directed thinking are held to a minimum, and the individual allows himself freely to let unconscious and preconscious material float into his mind" (Fromm, 1976, p. 560).

As the second concept, the ego-psychological theory delineates between primary and secondary processes solely based on their level of consciousness and not their relation to ego and id. In other words, the primary process is "the cognitive process of the unconscious ego. Secondary process, on the other hand, is a conscious ego function, a tool of reality testing … [which] dominates the everyday cognitive mode of the adult" (Fromm, 1976, p. 559).

To understand hypnotic phenomena, according to ego-psychology, one needs to consider that hypnosis is an altered state of consciousness characterized by ego-receptivity, where an observing ego (observing adult) is replaced by an experiencing ego (experiencing child). This state is dominated by the primary cognitive process. According to ego-psychology, this change explains why, during hypnosis, participants have so much imagery and fantasy, which are characteristic of primary-process thinking. However, one should note that if, during daily life, we choose to imagine the face of a friend, this is an act of the active ego. In contrast, during an altered state of consciousness, "if I allow the stream of consciousness to flow by, I am ego receptive, allowing imagery to arise from the unconscious or preconscious into conscious awareness" (Fromm, 1976, p. 565).

In evaluating the ego-psychological theory, one should note that it focuses more on the clinical effects of hypnosis rather than on the underlying cognitive processes. For instance, Fromm (1976, 1992) discusses that as hypnosis causes a regression to primary-process thinking and imagery, it is a great vessel for emotional learning that, in contrast to intellectual learning, does not require focused attention. However, intellectual learning best happens when participants use their rational, reality-oriented secondary-process thinking process. Thus, based on our understanding, the ego-psychological theory understands hypnotic phenomena by relying on an altered state of consciousness. Consequently, the gaps in the ability of the ego-psychological theory to explain the existing findings related to hypnotic phenomena are abundant. First, if hypnotic phenomena are caused by an altered state of consciousness, one should expect a different response to suggestions when represented during and outside hypnosis, which contradicts the literature (Braffman & Kirsch, 1999; Ludwig et al., 2014; Parris & Dienes, 2013). Further, the theory supposes that imagery is an essential part of hypnosis; however, research indicates that a group of high-hypnotizable participants use dissociative mechanisms to the exclusion of imagery (Barrett, 1996; Pekala, Kumar, & Marcano, 1995; Terhune, 2015; Terhune & Cardeña, 2010; Terhune, Cardena, & Lindgren, 2010, 2011).

Considering that the ego-psychological theory relies on primary-process thinking, it cannot explain the multifactorial structure of hypnotizability (Woody et al., 2005; Zahedi & Sommer, 2022). Further, the current understanding in the field that hypnotic phenomena are related to top-down cognition rather than bottom-up processes (Terhune et al., 2017) contradicts the assumption of primary rather than secondary-process thinking during hypnosis. For instance, it has been shown that cognitive processes, as measured by Stroop and other executive function tasks, are intact during hypnosis (Egner et al., 2005; Zahedi et al., 2017); however, see Jamieson and Sheehan (2004) for contradictory results. Additionally, the assumption that primary-process thinking is the dominant mode of processing during hypnosis results in the idea that hypnosis is more appropriate for emotional learning rather than intellectual learning. However, the enhancing effects of posthypnotic suggestions on executive functions (Landry et al., 2021; Lindelov et al., 2017; Zahedi et al., 2019; Zahedi et al., 2020b) show that intellectual learning is not only possible but also facilitated during hypnosis. It has been discussed that, similar to other psychoanalytic approaches, some of the concepts and structures assumed by the ego-psychological theory are not easily testable or falsifiable. However, recent advancements in technical and theoretical understanding of neurocognitive functions have provided an intriguing avenue for testing some of the core psychoanalytic assumptions, such as the existence of primary versus secondary thinking processes (Carhart-Harris & Friston, 2010).

One of the interesting assumptions of the ego-psychological theory is that hypnosis is related to unfocused attentional processes rather than focused ones. Accordingly, Zamansky and Clark (1986) investigated the effects of contradictory suggestions ("involved imagery") on hypnotic responsiveness. In their study, participants received contradictory suggestions while responding to the hypnotist's direct (target) suggestions. For instance, while participants were responding to the (target) suggestion to bend their (right) arm, the hypnotist asked them to imagine not being able to bend their arm. Notably, "involved imagery" contradictory-to-direct suggestions did not prevent medium- and high-hypnotic-suggestible participants from following target suggestions. Although the prediction of unfocused attentional processes might be in accordance with the results of Zamansky and Clark (1986), the assumptions based on which this prediction is formed, as discussed above, can be questioned. Therefore, it might be beneficial to reduce the assumptions that are required to reach the same prediction. Based on our understanding, this example shows that even though psychoanalytic approaches are insightful for clinical practices, due to their elaborated assumptions that are rooted in the psychoanalytic approach, they might not be as useful for elucidating the cognitive mechanisms of hypnotic phenomena.

2.2. Conditioning theories of hypnosis

Pavlovian or conditioning theories of hypnosis comprise another category of state theories, which try to explain hypnotic phenomena using state-focused approaches. We will discuss several variants of the conditioning theory (c.f., Barrios, 2001; Das, 1958; Edmonston, 1977) together since, in our opinion, they are too similar to warrant a separate discussion. Notably, the conditioning theories are founded on the behavioral experiments conducted by Hull (1933), and some of their assumptions are borrowed from this seminal work.

Edmonston (1977, 1991) describes the basic idea of Pavlovian theories in terms of neutral hypnosis, which is a form of relaxation that he calls anesis. The Pavlovian theory, however, can be described in more detail by examining the two tenets that Das (1958) proposes. These are: (I) repetition of a stimulus that has acquired inhibitory properties (i.e., should be neglected as it has no novel information) can cause a sleep-like state or drowsiness (i.e., an inhibitory state). Several such inhibitory states range from "hardly differing from wakefulness to states tending to deep sleep" (p. 82). The phase between sleep and wakefulness is called the hypnotic phase. (II) These states are caused by inhibiting the different cerebral cortices, starting with higher-order cognitive areas, spreading to motor areas, and finally engulfing sensory areas. Sleep is then the inhibition of the whole brain. Such states are required, as they are opposed to excitation and, hence, protect the system from unnecessary excitation by, for instance, extinguishing conditioned stimuli or irrelevant information. To explain why the hypnotic state causes hyper-suggestibility, Das (1958) refers to Pavlov (1941): "In hypnosis, we have a diminished positive tonus (in the cortex) as a consequence of irradiated inhibition. When on such a cortex, a word or order of the hypnotizer is directed to a definite point, the stimulus concentrates the excitatory process in the corresponding point and is immediately accompanied by negative induction, which causes it, without the slight opposition, to spread over the whole cortex; this is why the word or the order is completely isolated from all influences and is made an absolute, irrepressible, fatally-acting stimulus, even after the subject has returned to the waking state" (p. 108–109).

The basic issue with this formulation of hypnotic phenomena is that it confines hypnosis to relaxation and drowsiness (Cardeña & Spiegel, 1991). Yet many studies have shown that hypnosis can be evoked during strenuous physical activity (Banyai & Hilgard, 1976; Malott, 1984). Further, sleep cannot be considered a state of inhibition since it encompasses complex brain activities that serve specific psychological and mental functions (Cirelli & Tononi, 2008; Diekelmann & Born, 2010). Therefore, strong evidence contradicts the basic Pavlovian version.

Barrios (2001) advances a second, more nuanced version of conditioning theories. In "A Theory of Hypnosis Based on Principles of Condition and Inhibition," Barrios (2001) first defines conditioning as a situation where two stimuli are presented consecutively when the agent is paying attention to them, which is related to the stimulus-stimulus account of conditioning (Colwill & Rescorla, 1986). However, these stimuli can be cognitive (e.g., words associated with words) and do not necessarily have physical properties (e.g., bell associated with food). Second, he assumes that conditioning has two sides: associating stimulus A with stimulus B and simultaneously associating stimulus A with an inhibitory set mutually exclusive to stimulus B. Typically, the positive side is highlighted, but it is equally possible to associate stimulus A with just an inhibitory set. Notably, suggestions are conditioned responses to inhibit all contradictory stimuli to the response proposed by them. For instance, a suggestion that "a watermelon is on an obviously empty table" (Barrios, 2001, p. 186) works as it will inhibit contradictory sensory information (i.e., there is no watermelon) or incompatible cognitive stimuli (e.g., in this season, usually, there would be no watermelon). Consequently, participants can vividly see a watermelon. Hence, a suggestion is assumed to be associated with a cognitive stimulus triggering the desired response and an inhibitory set suppressing all incompatible stimuli and responses.

Barrios (2001) advances a second assumption that a positive response to a suggestion increases the possibility of responding to the next suggestions. Due to this property, hypnotic induction, besides activating an inhibitory set associated with hypnosis, will induce a state wherein it is more plausible that participants would respond to suggestions. Further, different factors can affect participants' suggestibility, including their expectations, motivations, attitudes, fears, and age.

According to our understanding, several questions cannot be addressed by the assumptions Barrios (2001) proposes. First, in contrast to reflexes, conditioning needs learning, or as Barrios (2001) puts it, conditioning is: "a result of the individual's previous experience" (p. 165). If one assumes that hypnotic phenomena are caused by a conditioned response of suppressing incompatible stimuli, then one should ask when and how participants formed these associations. On the other hand, if the conditioned response is relaxation, this theory also suffers from the same issues that pertain to other versions of conditioning theories. Notably, one cannot say that proposed associations arise from participants' expectations, as expectations are not turned into associations unless they become habitual responses through extensive training (Norman & Shallice, 1986). In some exemplary situations (Tse et al., 2007), even one trial is enough for memory consolidation and gaining hippocampal independency (i.e., habitual responses), but even that situation requires one trial of practice. Further, based on this assumption, one should expect that hypnotic suggestibility gradually increases as participants get more exposure to hypnosis. In contrast to this supposition, participants generally show stable or diminished hypnotic suggestibility scores when tested with the same hypnosis scale (Fassler et al., 2008; Meyer & Lynn, 2011; Piccione et al., 1989), which contradicts the hypothesis of conditioning theories.

Further, abundant evidence exists that hypnotic inductions often have little or no effect on participants' responsiveness (Lynn et al., 2017; Mazzoni et al., 2009; McGeown et al., 2012; but see Weitzenhoffer & Sjoberg, 1961) and may not be necessary for the effectiveness of suggestions (Parris & Dienes, 2013). Even when inductions enhance responsiveness, their effects are usually small compared to other predictors, such as responsiveness to targeted suggestions outside of hypnosis, motivation, fantasy-proneness, or absorption capabilities (Braffman & Kirsch, 1999; Lynn et al., 2015b). Although the context of suggestion (e.g., being presented with ideomotor versus cognitive suggestions) can affect participants' responsiveness (Woody et al., 2005), the order of presentation does not have any effect (Weekes & Lynn, 1990). Additionally, even though Barrios (2001) discusses factors that are related to participants'

suggestibility, they can only justify the existence of a G-factor underlying hypnotizability. To clarify, one can consider the effects of motivation as he discusses: "It is fairly obvious that if subjects are not very interested in being subjected to hypnotic induction, their chances of responding positively are much less" (Barrios, 2001, p. 183). These factors could explain the variation of hypnotic suggestibility if it had a unimodal structure. However, as discussed above, hypnotic suggestibility has a multifactorial structure with several distinguishable groups of high-suggestible participants (see section 1.4), which the conditioning theory cannot explain. To summarize, although conditioning theories suggest a straightforward explanation of hypnotic phenomena, they are restricted in their applicability. However, the principles of these theories, such as relating hypnotic responses to the inhibition of incompatible stimuli or highlighting the necessity of studying hypnosis in relation to psychophysiological measures, were noteworthy contributions of the perspective. These contributions have already been integrated more precisely into other approaches, such as dissociation theories, which we will discuss later. Finally, for the resolution of future development of this research trajectory, several questions should be addressed: What form of relaxation is addressed by the theory? For instance, does relaxation refer to muscular, autonomic, or central arousal? What is inhibition? Is it functional, physiological, or both, global or confined to specifically targeted stimuli? Can it be implemented through top-down or only bottom-up processes?

2.3. Sociocognitive theories of hypnosis

Sociocognitive theories are among the first accounts to embrace the contribution of top-down cognitive processes in responding to suggestions (Terhune et al., 2017). Sociocognitive theories highlight the critical role of participants' heuristic models and inner predictions in their responses (Lynn et al., 2019). Notably, prior to sociocognitive approaches providing a way for integrating variables such as motivation and demand characteristics as a core part of hypnosis, these variables were regarded as ubiquitous artifacts; for instance, Orne (1959) summarizing the state-of-art regarding theories of hypnosis mentions that the altered state of consciousness "may be regarded as the "essence" of hypnosis, with reference to which increased motivation and role-playing appear as artifacts" (p. 277). In this context, pioneers of sociocognitive approaches (e.g., Barber, 1969; Barber & Calverley, 1962) tried to explain hypnosis by falling back on artifacts alone without assuming the "essence" of hypnosis. Several relatively early yet highly influential sociocognitive theories are similar enough to be discussed together. Three such perspectives are selected based on our systematic criteria: (I) compliance, belief, and semantics in hypnosis (Wagstaff, 1991), (II) role theory (Coe & Sarbin, 1991), and (III) cognitive-behavioral perspective (Spanos, 1986; Spanos & Chaves, 1989).

Sociocognitive approaches make a fundamental assumption that separates them from other perspectives (for review, see Lynn & Rhue, 1991). That is, hypnotic phenomena can be explained by mundane and everyday social and cognitive processes, which eliminates the necessity of assuming a special condition, ability, or neurocognitive process to account for hypnosis (Barber, 1958; Barber & Calverley, 1962; Lynn et al., 2019; Lynn et al., 2023). Instead, to understand hypnotic phenomena, one should appreciate that hypnosis happens in an interactive context, i.e., a hypnotic context, involving two parties: the hypnotist and the participant. Both parties assume specific roles, which are informed based on social norms and culturally transmitted beliefs, attitudes, and expectations (Barber, 1958; Coe & Sarbin, 1991). However, these roles, especially for the participant, can be modulated based on hypnotic communications, such as the induction, the wording of suggestions (Gorassini & Spanos, 1986; Spanos et al., 1985), task motivation, and expectancies induced by the hypnotist (Barber, 1958; Barber & Wilson, 1977); however, for counterevidence, see (Benham et al., 1998; Lifshitz et al., 2012). This fundamental assumption explains why involuntariness while responding to hypnotic suggestions is viewed as a byproduct of expectations and interpretations rather than a reflection of a special state of consciousness (Lynn et al., 1984; Weekes & Lynn, 1990). For instance, attributions of responsiveness to the hypnotist or hypnosis itself can alter SoA in the participant (Lynn et al., 1984; Weekes & Lynn, 1990). Therefore, alterations in SoA during hypnosis may be better explained as the result of not attributing a response to the exertion of volitional effort (Lynn et al., 1990), which might depend on induced or context-driven expectancies associated with hypnosis generally (Lynn et al., 1984).

In their role theory, Coe and Sarbin (1991) use dramaturgical analogies to describe hypnotic behavior. For instance, the authors discuss that hypnotic interaction is akin to theatrical performance, in which both parties enact their respective roles. On the other hand, Spanos (1971) highlights two social and cognitive processes for explaining hypnotic phenomena. (I) Attitudes, beliefs, interpretations of suggestions, and demand characteristics induced in the participant, for instance, by the passive wording of suggestions, result in alterations of SoA. (II) The strategic and goal-directed nature of hypnotic responsiveness is critical for understanding participants' objective and subjective responses. Finally, Wagstaff (1991) argues that hypnotic phenomena cannot necessarily be explained by a singular set of elements, which is implied if one accepts that a special state of consciousness causes hypnosis. Instead, different hypnotic phenomena might be better explained separately, each relying on a unique and intricate explanation. For instance, responses to different suggestions can be products of compliance, imagination, expectancy, or a unique combination of them.

In discussing sociocognitive approaches, Evans (2000) points to a critical consideration. That is, positive and negative expectations regarding the procedure, i.e., placebo and nocebo, might explain some but not all aspects of hypnotic phenomena. By conducting a structural equation modeling of hypnotic responses, Benham et al. (2006) showed that "Expectancies are neither irrelevant nor definitive," meaning even though they affect responses, other cognitive processes (i.e., cognitive control) are involved in responding to suggestions. This finding is also echoed by the results of Zahedi and Sommer (2022), showing that hypnotizability is best described by a bifactor model.

One, however, should note that sociocognitive models are well-suited to integrate other cognitive processes to explain hypnotic phenomena more comprehensively (for a novel attempt, see Zahedi et al., 2024). Nevertheless, few authors have tried to propose and empirically validate a delineated set of cognitive processes that account for the variability in hypnotic responding (Lynn et al., 2023). There are some cases where several processes are suggested, for example, the response-set theory by Lynn et al. (2023), which will be

discussed below.

Finally, the focus of sociocognitive approaches on conscious control has also been criticized. For instance, Bowers and Davidson (1991) criticized Spanos (1991) for focusing on conscious control and strategic enactments to the exclusion of automatic or unconscious responses. Bowers and Davidson (1991) reasonably mention that "purposeful behavior need not flow from conscious intents and purposes" (p. 136). However, this criticism is already accepted and incorporated by sociocognitive approaches (Spanos, 1986). These newer versions of sociocognitive approaches attempt to integrate automatic behaviors in their explanation of hypnotic responsiveness, which will be discussed in depth in the following section.

2.3.1. Response-set theory and integrative social-cognitive model

The response-set theory (Kirsch & Lynn, 1997) and the integrative model (Lynn et al., 2015b) fall within the domain of sociocognitive models, as hypnotic responses are viewed as goal-directed, strategic (e.g., cognitive-behavioral activities required to fulfill suggested demands), aligned with the motivations and beliefs of participants, and under their control much like everyday activities (Lynn et al., 2015b). The theory further assumes that all actions, whether quotidian or induced by suggestions, learned or novel, have automatic precursors (i.e., response sets) and are activated by environmental cues and internal experiences. However, two response sets can be distinguished: intention implementation and response expectancy. In intention implementation, the agent interprets the situation as when *X* happens, I will do *Y*, but in response expectancy, the relation is interpreted as when *X* happens, *Y* will occur. Responses to hypnotic suggestions are instigated automatically by triggering precursors of actions outlined by suggestions, but participants have a general expectancy that during hypnosis, actions happen involuntarily. Therefore, during hypnosis, response expectancy, instead of intention implementation, is relevant.

Kirsch and Lynn (1997) argue that "although responses may be triggered automatically, suggestion alone is not sufficient to trigger them" (p. 341). Instead, suggestions alter subjective experiences, which bring about objective overt responses. For instance, in response to an arm-lifting suggestion, participants expect their arms to "feel light enough to move upward automatically." The authors argue that "[t]he subjective experiences of … lightness … [is] generated, at least in part, by the expectancies of … [its] occurrence." These self-fulfilling expectancies work as "the situational cues that must be present for the response to be triggered" (Kirsch & Lynn, 1997, p. 341). In other words, the arm-lifting suggestion creates a self-fulfilling expectancy of lightness, which works as a cue to trigger the response of lifting one's arm.

Hypnotic-suggestion-induced responses, however, are interpreted as non-volitional since participants' interpretation "is not that they are intentionally moving [their arms], but rather that they are not inhibiting a movement that is consistent with their subjective experience [of lightness in their arms]" (Kirsch & Lynn, 1997, p. 341). An alteration in subjective SoA during hypnotic-suggestion-triggered responses is essential. For example, in response to the arm-lifting suggestion, "[m]ost people lift their arms only if they succeed in generating a sensation of lightness sufficient to allow them to interpret their behavior as non-volitional" (Kirsch & Lynn, 1997, p. 341). Further, the authors discuss that attributes, such as involuntariness, are concurrent or "post-facto" interpretations. These interpretations are derived from expectations about the hypnotic situation and perceiving automatic precursors of actions, which are usually ignored.

The response-set and integrative model maintain that since there is a high correlation between non-hypnotic and hypnotic suggestibility (Braffman & Kirsch, 1999), objective responses to hypnotic suggestions are caused by similar mechanisms underlying responses to direct verbal suggestions. That is, the same imaginative suggestions administered in the non-hypnotic context elicit comparable subjective experiences and feelings of involuntariness when the demand characteristics point to such feelings (Kirsch et al., 2008, Study 2; Meyer & Lynn, 2011). However, reports of experiencing a hypnotic state are more likely when people receive a prior hypnotic induction (Kirsch et al., 2008, Study 1). Nevertheless, according to the integrative model, hypnotic suggestions, compared to non-hypnotic suggestions, can lead to higher responsiveness and non-volitional feelings due to positive expectancies associated with hypnosis. As Kirsch and Lynn (1998b) note, "involuntariness is part of the culturally defined hypnotic role, and both research and historical data indicate that hypnotic behavior is almost invariably consistent with participants' role perceptions (reviewed by Kirsch, 1991)" (p. 72).

To support their claim that all actions are instigated automatically, the response-set and integrative model refer to contention scheduling theory (Norman & Shallice, 1986), which postulates three domains of actions. Two domains are related to (1) reflexive schemata that cannot be controlled at all and (2) scripts that are flexibly controlled by the supervisory attentional system (SAS). The third domain is in charge of actions between these two extremes and is called contention scheduling (Cooper & Shallice, 2000). Norman and Shallice (1986) assume that when actions are trained enough, source schemata are created. Contention scheduling is in control when several "source schemata" compete in "the determination of their activation value" and ensures that the schema that first exceeds an activation threshold will be selected. Hence, in non-demanding conditions (i.e., for which the agent has specific schemata), contention scheduling can operate without any input from the SAS. However, when novel responses are required, or a well-learned response has to be suppressed in favor of a novel response (i.e., demanding conditions), the SAS is needed. In these demanding situations (i.e., flexibly controlled scripts), the SAS interferes by implementing cognitive control and biasing the activation of different schemata and ensures that the correct response is selected.

Are "all actions, hypnotic or otherwise, … at the moment of activation triggered automatically" (Lynn & Green, 2011; p. 281)? Kirsch and Lynn (1997) gave examples that even creative actions, such as professional piano playing or communicating about new topics in one's mother tongue, are instigated automatically and executed with little to no burden on attentional resources. Notably, the intention to play the piano is conscious, but as the action is well-learned, it can be handled by contention scheduling without conscious awareness. Similarly, the response-set theory argues that hypnotized participants might be aware of their goal of being responsive, but the responses can be executed with minimal consciousness and a high degree of automaticity (Green & Lynn, 2011; Kirsch & Lynn,

1997; Lynn et al., 2015b; Lynn et al., 1990). This explanation ignores the fact that not all actions can be handled by contention scheduling. For instance, a person playing piano for the first time or learning a foreign language, which contains new vowels and consonants unfamiliar to the speaker, needs to acquire and learn these new contingencies first. These new responses cannot have substantial automatic precursors. Learning new responses is resource-consuming and cannot be handled by contention scheduling but only through the SAS. Even in the simplest form of learning, such as trace conditioning, a conscious and resource-consuming effort to create novel associations (e.g., between conditioned and unconditioned stimuli) is required (Clark et al., 2002).

One can suggest that the response-set theory either assumes the SAS is not used during hypnosis or SAS cannot be affected by suggestion-triggered responses. Suppose the response-set theory assumes that SAS is not needed during hypnosis. In that case, participants should be unable to perform any task requiring executive functions during hypnosis because such tasks require the SAS. Although a dispute exists regarding whether participants perform executive function tasks better or worse during hypnosis without task-relevant suggestions (Egner et al., 2005; Nemeth et al., 2013; Zahedi et al., 2017), it is not disputed that participants can perform such tasks (Jamieson & Woody, 2007; Parris, 2017). What about the immunity of the SAS to hypnosis effects? As reviewed above, executive functions (Baddeley, 2003; Diamond, 2013; Miyake et al., 2000), which are closely related to the concept of the SAS, can be affected by task-relevant suggestions. Consequently, suggestions can help participants to learn new trigger-response or response-outcome contingencies. If one assumes an immunity for the SAS to (hypnotic or direct verbal) suggestions, these observations cannot be explained.

Lynn and Green (2011) tried to support the claim of the response-set theory by referring to the concept of the unconscious will (Custers & Aarts, 2010), a more recent account of unconscious decision-making and cognitive control. Custers and Aarts (2010) mention that the *intention* to act can spring from outside of consciousness, and further, consciousness is not necessary to *evaluate the reward value* of an action already existing *in one's repertoire*. This proposition does not imply that all actions are triggered automatically at the moment of activation. New actions without established stimulus–response or response-outcome associations are not part of one's repertoire and must be learned first (Colwill, 1993; Colwill & Rescorla, 1986). Further, the unconscious will account assumes that the intention to pursue a goal can be activated unconsciously. However, in these situations, participants are not less eager to attribute their actions to themselves. Quite the contrary, if unconsciously activated goals and outcomes are subsequently realized and perceived in the real world, the conscious experience of self-agency should be expanded, and participants might even attribute random events to themselves (Aarts et al., 2009). On the other hand, the response-set theory assumes that the intention to be a good responder is usually quite conscious (Lynn & Sivec, 1992); however, as the processes involved in responding are automatized, they will become unconscious and attributed to external events. Hence, the "unconscious will" cannot be used to justify the response set theory's assumption.

Several other issues should be discussed here. First, as the response-set theory assumes a general mechanism underlying all suggestions, it cannot explain the multifactorial and typological structure of suggestibility scores (see section 1.4). However, in a new revision of the response set theory (Lynn et al., 2023), the authors discuss how, by trimming back to the core of the theory and focusing on expectancies, one can implement other top-down cognitive functions, such as top-down inhibition or imagination, alongside expectancies in the response set theory. This approach, which relies on using participants' heuristic models for implementing their expectancies along with other cognitive functions, can possibly make the response set theory able to account for the multifactorial structure of hypnotizability and multiple groups of high hypnotizables; nevertheless, this conceptualization should be further developed before one can employ it to generate testable hypotheses based on it.

Second, the integrative model argues that cognitive components, such as responsiveness to direct verbal (i.e., imaginative) non-hypnotic suggestions and psychosocial factors (e.g., motivations and expectancies), strongly contribute to hypnotic responsiveness. Together, these variables account for more than 50 percent of the variability in hypnotic responsiveness (Lynn et al., 2015b). Nevertheless, the integrative model, which is an "open model" amenable to the inclusion of additional variables, needs to specify such variables to better account for the variance in hypnotic responsiveness (Lynn et al., 2023), an imperative that also applies to other sociocognitive theories.

Third, although the response-set theory's explanation fits movement suggestions, the perceptual suggestions cause a theoretical issue. One can demonstrate this by applying the response-set theory's explanation to a perceptual suggestion. For instance, consider the same arm-lifting item discussed above but without any movement: Participants have self-fulfilling expectancies to change their perception (e.g., hand lightness), and therefore, they alter their perception and feel a lightness in their hands. In this case, the response-set theory has little explanatory value regarding why the phenomenon has happened. Finally, some of the response-set assumptions are extremely difficult, if not impossible, to be tested and falsified. For example, it is difficult to empirically dissociate between self-fulfilling expectancies, alterations in inner experiences, and changes in SoA. Moreover, the theory does not specify how one could assess and, therefore, potentially falsify the automatic triggering of a suggestion-related response at the exact moment of its execution.

Even if aspects of the response-set model are not sustainable in their original format, a stripped-down version of it has substantial explanatory power. Especially the postulation of the theory that participants' internal and generative models shape perception and SoA is currently the dominant view in the field of neuroscience and is well-aligned with experimental observations (Clark, 2013; Friston, 2010, 2012; Friston et al., 2020). There is an undeniable alignment between the response-set theory and Helmholtz's notion that perception is "the brain's best-fitting model for the information entering the senses" (Winkler & Czigler, 2012, p. 132). This shows how response-set theory's fundamental notions present a plausible explanation for the alterations in SoA when responding to hypnotic suggestions.

2.4. Dissociation and decoupling theories

Historically, dissociation theories are among the first truly scientific theories of hypnosis. They have exerted enormous influence on

contemporary thinking about hypnosis. The dissociation theories' contention that hypnosis involves a mental state during which ordinarily conscious cognitive control processes are inaccessible or disrupted has stimulated substantial research (for review, see Kirsch & Lynn, 1995; Kirsch & Lynn, 1998a; Kirsch & Lynn, 1998b). We will distinguish prominent variants of dissociation theories that have attracted empirical attention.

2.4.1. Neo-Dissociation theory

Ernest Hilgard's seminal "neo-dissociation" account (Hilgard, 1973, 1977) assumes that hypnosis creates two "amnestic barriers" (Woody & Bowers, 1994). The first divides the stream of consciousness into two subsystems, and a second barrier limits the access of one of these subsystems to communication channels. The two consciousness subsystems assume different roles; the one with access to communication channels will (a) ordinarily subserve planning and monitoring personality functions. The other subsystem (b) facilitates executing suggestion-induced responses (i.e., changes in behavior, perception, and cognition) and experiencing them as non-volitional. Even though participants maintain normal cognitive functioning, a part of perceptual information and cognitive control processes becomes inaccessible or dissociated from the dominant consciousness (i.e., the so-called hidden observer). Hence, a diminished SoA in hypnosis is ascribed to the inaccessibility of cognitive processes and information hidden behind the amnestic barrier. This postulation can explain the reaction of hypnotized participants, for instance, to a pain-relieving suggestion: "there are commonly no changes in the underlying physiological indicators of pain, even though the subject feels no pain" (Hilgard, 1973, p. 396).

In response to what "characterize[s] the relatively enduring talent that makes some individuals more hypnotizable than others" (p. 48–49), Hilgard (1977), in reference to hypnotic pain reduction, maintained that nearly everyone could respond to direct verbal suggestions to some extent, but only high hypnotizable participants respond on the basis of an "amnesia-like process" (p. 52). The high-hypnotizable participants, "who can erect amnestic barriers" (Hilgard, 1977, p. 55), will additionally benefit from receiving pain-reduction suggestions during hypnosis beyond relaxation, anxiety reduction, and diversion of attention. He goes on to mention that "only a small proportion of the population can be hypnotized sufficiently to yield substantial amnesia, hallucinations, and other evidence of profound hypnotic involvement" (Hilgard, 1977, p. 55).

The neo-dissociation account is currently out of favor even among some advocates of dissociation theory (Jamieson & Woody, 2007; Woody & Bowers, 1994), mainly because of the assumption that "amnesia-related processes" are necessary for being a "real" responder. Considering that spontaneous amnesia is a rare phenomenon during hypnosis, grounding a definition on an exceptional phenomenon can be perilous. Additionally, research inspired by Hilgard's theory indicate that apparent divisions in the personality (e.g., hidden observers) during hypnosis is suggestion-induced rather than spontaneously occurring phenomena (Kirsch & Lynn, 1998a; Woody & Bowers, 1994).

Notably, some aspects of neo-dissociation theory are compatible with other theories. Lynn and Green (2011) proposed a path toward theoretical rapprochement by suggesting that the response-set and neo-dissociation theories are similar in that both acknowledge that hypnotized participants often respond to suggestions with alterations in their ordinary sense of volition. However, the similarities between the two theories mostly end here. Laurence and Perry (1981) advanced one way to connect the neo-dissociation theory to other theories. They replicated Hilgard's findings that around 40 % of high-hypnotizable participants showed the hidden observer effect since they "reported that the pain that was not experienced during analgesia nevertheless registered at another level when hidden observer instructions were administered" (Laurence & Perry, 1981, p. 342). The same group of participants, when responding to age regression suggestion, experienced "duality," in which they could vividly imagine being a five-year-old child again, although they were aware of their adulthood. On the other hand, the other group of high-hypnotizable participants, who did not experience the hidden observer effect, could not write a sentence when experiencing age regression as well, as if they became a child incapable of writing a sentence. Laurence and Perry (1981) suggested the observed differences might indicate different cognitive strategies that are used by high-hypnotizable participants; that is, the former group might rely more on selective attention and the latter imagery/absorption.

Even though immensely influential, the neo-dissociation theory's claim that the amnestic barrier divides consciousness limits its applicability to the few participants experiencing hypnotic amnesia, as Hilgard himself argued (Hilgard, 1973, 1977). This issue caused newer versions of the dissociation theory to adopt different approaches to integrate and assimilate Hilgard's basic idea that during hypnosis, some conscious cognitive control processes are inaccessible to participants.

2.4.2. The integrative model of Hypnosis: Suggestibility, Absorption, and dissociation

In the integrative model of hypnosis, Cardeña and Spiegel (1991) advance a variant of dissociation theory, which, to this day, is a strong contributor to the field. This fact is noticeable when one considers that a prominent definition of hypnosis, adopted by the Hypnosis Division of the American Psychological Association (Elkins et al., 2015), closely resembles this version of dissociation theory.

To understand why hypnosis is related to increased direct verbal suggestibility, Cardeña and Spiegel (1991) discuss that the state of consciousness during hypnosis is an aberrant form of consciousness. This state can be defined as a state with a "single total attention that fully engages one's representational (i.e., perceptual, imaginative, and ideational) resources" (p. 99). Therefore, the hypnotic state of consciousness is starkly related to increased absorption caused by hypnotic induction. The authors contrast this to the normal stream of consciousness, which is composed of spontaneous and "brief ever-changing associations whose claim to continuity, rationality, and reality-orientation is tenuous" (p. 94).

The special state of consciousness during hypnosis has a second characteristic besides increased absorption, that is, dissociation, which is essential for understanding alterations in SoA. Dissociation, however, is not conceived in the same way as Hilgard (1977) envisions it. Hilgard (1977) sees dissociation as a split between two parallel streams of consciousness. In contrast, dissociation in the

integrative model of hypnosis refers to feeling alienated from one's actions and responses and attributing them to external sources, e.g., to the hypnotist. In order to explain why hypnosis causes dissociation, the authors discuss three factors. First, during hypnosis, behavior is initiated by another agent (i.e., the hypnotist). Second, due to increased absorption, the automaticity of actions, which also accompanies normal daily activities, is experienced as "being of a more intense and salient nature" (Cardeña & Spiegel, 1991, p. 103). Finally, the continuous and non-shifting attention caused by increased absorption will force participants to perceive the automaticity of actions as involuntariness. Summarizing, the integrative model of hypnosis assumes these three elements together will describe hypnotic phenomena fully: increased absorption, dissociation, and higher suggestibility, which is the result of the other two elements.

The first issue regarding the theory is discussed by the authors themselves. The integrative model is focused on ideomotor suggestions and has limited applicability beyond them. For instance, if hypnosis is a state of consciousness marked by increased attention to proprioceptive input, then hypnotic analgesia, presumably related to the suppression of or distraction from sensory inputs (Thompson et al., 2019), will be difficult to explain. Moreover, if a particular state of consciousness during hypnosis causes hypnotic phenomena, posthypnotic suggestions, coming into effect only after the termination of hypnosis, should be related to other processes not covered by the theory.

The integrative model of hypnosis needs to address several other challenges. First, Cardeña and Spiegel (1991) claim that their theory can address the multifactorial structure of hypnosis, as their theory relates hypnotic phenomena to three different elements. However, they neglect the fact that these elements are heavily interdependent. In other words, dissociation heavily depends on absorption to the extent that one might suggest it is a byproduct of the latter (Holmes et al., 2005). Furthermore, increased suggestibility during hypnosis directly results from absorption and dissociation. Therefore, the model cannot explain the existence of several different groups of suggestions, each relying on separate cognitive processes (Woody et al., 2005; Zahedi & Sommer, 2022). Nor is there any provision in their theory for explaining the existence of multiple sub-groups of high-hypnotizable individuals (Terhune, 2015; Terhune et al., 2011). However, it might be discussed that although dissociation may be considered as an outcome of absorption, the extent to which the former emerges from the latter will vary in different individuals and in response to different suggestions. Hence, different types of suggestions may arise, which, for instance, require absorption with lower versus higher dissociation. Nevertheless, in this case, the absorption and dissociation should be defined as semi-independent measures, which is theoretically challenging and not aligned with the current structure of the theory.

Further, contrary to what the theory predicts, there is typically a very small correlation, if any, between hypnotizability and attentional regulation (Varga et al., 2011) or dissociation (Dienes et al., 2009; Kihlstrom et al., 1994). Finally, if hypnotic phenomena are attributed to a special state of consciousness, the observed correlation between responsiveness to hypnotic and non-hypnotic suggestions (Braffman & Kirsch, 1999; Parris & Dienes, 2013) is difficult to explain. Together, even though the integrative model of hypnosis presents a creative and influential framework for understanding hypnotic phenomena, its most significant contribution to the field is its general ideas rather than a detailed and empirically supported account of the processes involved per se.

2.4.3. *Dissociated control theory*

Woody and Bowers (1994) proposed the third variant of the dissociation theory, which was later reframed as the decoupling theory (Egner et al., 2005; Egner & Raz, 2007; Jamieson & Sheehan, 2004) and the dissociated control theory (Jamieson & Woody, 2007). The basic assumption is that during hypnosis, frontal lobe functions are disabled or disrupted. The sense of lack of everyday agency is thus not an illusion, in contrast to neo-dissociation hypotheses (Woody & Bowers, 1994). Instead, involuntariness occurs because higher cognitive control processes are disrupted, and participants cannot relate their actions to intention implementation or planning (Brown & Oakley, 2004; Jamieson & Woody, 2007; Woody & Bowers, 1994).

Variants of dissociation theories mainly diverge in answering which higher-order cognitive functions are disrupted during hypnosis. Employing contention scheduling (see section 2.3.1), Woody and Bowers (1994) claimed that hypnosis disables the SAS. Accordingly, participants will act only based on lower-level cognitive control processes guided by contention scheduling. According to Norman and Shallice (1986), contention scheduling is in charge when no novel action is required. In other words, contention scheduling is related to situations in which several source schemata are activated, and contention scheduling is only responsible for selecting the first schema that reaches a certain threshold. If cognitive control is required, for example, if a prepotent but irrelevant response has to be inhibited, the SAS must interfere. As Brown and Oakley (2004) and Jamieson and Woody (2007) observed, if Woody and Bowers' (1994) contention that the SAS is disabled during hypnosis were correct, participants should be unable to perform any executive function-based task during hypnosis because such tasks require the SAS. Although a dispute exists regarding whether participants perform executive function tasks better or worse during neutral hypnosis (Egner et al., 2005; Nemeth et al., 2013; Zahedi et al., 2017), it is accepted that participants can perform them (Jamieson & Woody, 2007; Parris, 2017). Because hypnotized participants can still deploy executive functions during hypnosis, the SAS cannot be (completely) disabled.

2.4.4. *Decoupling [control] theory*

To account for essentially unimpaired executive functions during hypnosis, Jamieson and Sheehan (2004) and Egner et al. (2005) suggested that only the cognitive monitoring part of the SAS is disabled (decoupled). The decoupling account is based on the conflict monitoring theory (Botvinick et al., 2001), which distinguishes cognitive control from monitoring processes at anatomical and functional levels (Botvinick et al., 2004). Monitoring for cognitive conflicts takes place in the anterior cingulate cortex (ACC), whereas cognitive control processes are initiated in the dorsolateral prefrontal cortex (DLPFC). Indeed, many studies (e.g., Botvinick et al., 2004; Carter et al., 2000; Kerns et al., 2004) indicate that ACC activation is related to evaluative but not regulative processes. In other words, ACC activation is related to conflict detection and signals the need for implementing cognitive control but is not directly engaged in its implementation. Accordingly, the decoupling account claims that hypnotized participants can still perform executive

Table 1
The comparative summary of prominent theories of hypnosis highlighting their theoretical foci and their explanatory power.

Theory [A]	Focus of Theory [B]	Main sources	Objective Changes [C]					Alterations in SoA and SoR [C]		Hypnotic Responsiveness [C]		Neural Mechanisms [C]
			Direct Motor Movements	Challenge Motor Movements	Hallucinations	Enhancing Cognoitive Tasks Performance	Hypnotic Amnesia	Involuntariness and Effortlessness	Sense of Conviction	Multiple Suggestibilities	Groups of High-Hypnotizables	
Psychoanalytic Theories of Hypnosis	(1) Primary-Process Thinking and (2) Transient, Revocable Altered State of Consciousness	(Gill & Brenman, 1959; Nash, 2008)	X	X	–	–	–	X	X	–	–	–
Ego-Psychological Theory	Ego-Receptivity	(Fromm, 1992)	X	X	–	–	–	X	X	–	–	–
Conditioning Theories	Learned Conditioned Relaxation Response	(Barrios, 2001; Das, 1958; Edmonston, 1991)	X	X	–	–	–	–	–	–	–	(X)
Sociocognitive Theories	Expectancies and Contextual Variables	(Coe & Sarbin, 1991; Wagstaff, 1991), (Spanos, 1986; Spanos & Chaves, 1989)	X	X	–	–	–	(X)	(X)	–	–	–
Response-Set Theory	Intention Implementation vs. Response Expectancy	(Kirsch, 2000; Lynn et al., 2023; Lynn et al., 2015b)	X	X	(X)	–	(X)	X	X	(X)	(X)	–
Neo-Dissociation Theory	Divisions of Consciousness	(Hilgard, 1973, 1977)	X	X	X	–	X	X	X	–	–	–
The Integrative Model	Suggestibility, Absorption, and Dissociation	(Cardeña & Spiegel, 1991)	X	(X)	(X)	–	–	X	X	(X)	–	–
Dissociated Control Theory	Disruption of Higher Cognitive Mechanisms	(Jamieson & Woody, 2007; Woody & Bowers, 1994)	X	X	(X)	–	–	X	X	–	–	(X)
Decoupling Theory	Disconnection of Monitoring and Cognitive Processes	(Egner et al., 2005; Egner & Raz, 2007; Jamieson & Sheehan, 2004)	X	X	(X)	(X)	–	X	X	(X)	–	X
Unified Cognitive Theory	Different Styles of Responsiveness	(Brown & Oakley, 2004; Sheehan et al., 1978)	X	X	(X)	–	(X)	X	X	–	X	–
Three-Dimensional Comprehensive Theory	Different Groups of Highly Hypnotizable Participants	(Barber, 1969; Barber, 1999; Barber, 2000; Barber & Calverley, 1962)	X	X	(X)	–	(X)	(X)	(X)	–	(X)	–

(*continued on next page*)

Table 1 (*continued*)

Theory [A]	Focus of Theory [B]	Main sources	Objective Changes [C]					Alterations in SoA and SoR [C]		Hypnotic Responsiveness [C]		Neural Mechanisms [C]
			Direct Motor Movements	Challenge Motor Movements	Hallucinations	Enhancing Cognoitive Tasks Performance	Hypnotic Amnesia	Involuntariness and Effortlessness	Sense of Conviction	Multiple Suggestibilities	Groups of High-Hypnotizables	
Three Dimensions of Hypnotic Depth	Role-Taking, Trance Depth, and Depth of Archaic Involvement	(Shor, 1959, 1962)	X	X	(X)	–	–	(X)	(X)	–	(X)	–
Multifactorial Model	Attentioanl Dissociation	(Evans, 2000)	X	X	(X)	–	–	X	X	–	–	–
Relational Theories	The Interaction Between Hypnotist and Subject	(Bányai, 1998; Zelinka et al., 2014)	X	(X)	–	–	–	–	–	–	–	X
Ericksonian Theories	Clinical Effects of Hypnosis	(Erickson, 1958; Erickson & Rossi, 1976; Rossi, 1982)	X	(X)	(X)	–	–	–	(X)	(X)	–	–
Cold Control Theory	Disruption of Ascriptive Metacognition	(Dienes & Perner, 2007)	X	X	X	–	–	X	X	–	–	X
Discrepancy Attribution Theory	Enhanced Fluency	(Barnier & Mitchell, 2005; Barnier et al., 2008)	X	X	(X)	–	–	X	(X)	–	–	–
Interoceptive coding Model	Elimination of Higher-Order Predictions	(Jamieson, 2016; Jamieson, 2018, 2021)	X	X	(X)	–	(X)	X	X	(X)	–	X
Predictive Coding Model	Sustained Prediction Errors	(Martin & Pacherie, 2019)	X	(X)	(X)	–	–	X	X	–	–	(X)

[A] For detailed descriptions of each phenomenon and theory, see the text.

[B] Refers to the theoretical structure that best represents a theory, which might be considered the independent variable(s) that a theory uses to explain hypnotic phenomena.

[C] For a detailed description of these phenomena, see Section 1.1 – 1.4. These factors represent dependent variables that a successful theory should be able to explain. The main focus is whether a theory tries to explain a phenomenon, regardless of its congruity with observations: X: explicit and consistent explanation; (X): although the theory does not explain explicitly, it can be inferred from the theory; –: no explanation or severely inconsistent.

function tasks during hypnosis because they can initiate executive functions. For instance, if necessary, hypnotized participants can inhibit a prepotent response and, instead, select a more task-relevant one, although probably less successfully than during non-hypnotic conditions. However, the implementation of executive functions is supposed to be inflexible and cannot be modulated by internal monitoring signals since monitoring and cognitive processes are disconnected (Egner et al., 2005; Jamieson & Sheehan, 2004).

Two points need to be discussed about the new dissociative conjunction. First, Kerns et al. (2004) found that lower activation of the ACC in a given trial predicts decreased performance (e.g., longer reaction times) in the subsequent trial. Following Egner et al.'s (2005) suggestion that during hypnosis, the ACC and DLPFC are disconnected, one should expect that hypnotized participants do not detect the need to implement cognitive control, which should severely deteriorate performance (e.g., increased reaction times). However, many studies have failed to observe hypnosis-related performance decrements (e.g., Egner et al., 2005; Zahedi et al., 2017).

To address this contradiction, Jamieson and Woody (2007) proposed that hypnosis affects the outgoing signals from the rostral section of the ACC and not from the dorsal ACC. They explained further that the dorsal ACC, related to conflict monitoring, should be unaffected by hypnosis, but the rostral ACC, which is associated with error monitoring and feedback evaluation, is hampered. Therefore, they claimed that even though hypnotized participants perform well in executive function tasks, they cannot enhance their performance. Although the dorsal and rostral ACC are anatomically and functionally distinguishable (Du et al., 2020; Salehinejad et al., 2021), the assumed functions require further empirical investigations before being applied. For instance, in some theoretical accounts, both conflict detection (Botvinick, 2007; Botvinick et al., 2001; Botvinick et al., 2004) and monitoring of action outcomes and subsequently adjusting behavior based on evaluation of action outcomes (Botvinick, 2007; Ide et al., 2013) are attributed to the dorsal ACC. Further, many studies have shown that both prediction-based signals and outcome evaluation signals originate from the posterior and middorsal regions of the ACC (Botvinick, 2007; Ide et al., 2013; Jahn et al., 2014). Therefore, these two sets of functions might overlap, both anatomically and cognitively (Botvinick, 2007). This issue challenges the claim that during hypnosis, one set of these functions is intact, whereas the other set is blocked.

Second, and more importantly, as mentioned above, one of the major predictions of the dissociation theory is the alleged incapability of hypnotized participants to enhance their performance in executive function tasks. However, as already reviewed, the capability of task-relevant posthypnotic suggestions to enhance performance in executive function tasks is one of the best-established findings in the hypnosis literature (e.g., Lifshitz et al., 2013; Lindelov et al., 2017; Zahedi et al., 2020a).

Egner and Raz (2007) tried to reconcile the performance enhancements in executive function tasks in response to task-relevant posthypnotic suggestions with the decoupling account. However, in doing so, they retreated to the basic concepts of contention scheduling. They suggested that hypnotized participants who receive task-relevant posthypnotic suggestions, despite being hampered in using their SAS, perform more automatically, akin to relying on contention scheduling. As mentioned above, contention scheduling is only applicable to source schemata, that is, well-learned, automatic responses. As Zahedi et al. (2020b) discussed, Egner and Raz's (2007) suggestion is only plausible if: (1) participants have learned a task-appropriate, novel response to the point that it has become semi-automatic. Therefore, this "new" response will be capable of overriding a prepotent response without employing the SAS. Alternatively, (2) bottom-up processes have been modified to disrupt the prepotent response (e.g., becoming temporarily dyslexic during the Stroop task), and therefore, the SAS is not required anymore. Hypothesis 1 contradicts the basic assumptions of the dissociation theory, as learning requires the coordination between cognitive control and monitoring (e.g., Gobel et al., 2011; van der Graaf et al., 2006). Hypothesis 2 is at variance with observations that posthypnotic suggestions can affect performance in updating tasks (e.g., Lindelov et al., 2017; Zahedi et al., 2020b), where changes in bottom-up processes cannot significantly enhance performance (cf. Zahedi et al., 2020b). Hence, the decoupling account appears unsuited to explain performance enhancements due to hypnotic and posthypnotic suggestions.

Another limitation of dissociation theories is their inability to address the multifactorial structure of hypnotic suggestibility or the existence of multiple groups of highly hypnotizable participants since they assume a single cognitive mechanism underlying all suggestion-induced responses (see section 1.4). A possible solution for explaining the individual differences in hypnotizability is to reduce the assumption of complete decoupling [or dissociation] to a partial and adaptive one (i.e., related to top-down rather than bottom-up), which might vary across participants and over time in response to different suggestions. However, in this case, some other cognitive processes should still be assumed to account for the whole range of hypnotic phenomena.

2.5. Multicomponent theories of hypnosis

Studies using innovative methods, such as the experiential analysis technique (Sheehan et al., 1978), showed that there are several groups of highly hypnotizable participants, with each group using distinguishable strategies or skills (Barrett, 1996; McConkey, Glisky, & Kihlstrom, 1989; Pekala, Kumar, & Marcano, 1995; Sheehan, McConkey, & Cross, 1978). These results inspired a new approach to understanding hypnotic responses to become popular. This approach, which may be best termed multicomponent, focuses on the multifaceted nature of hypnotic responses and their individualized determinants. In a nutshell, Sheehan (1991) and McConkey (1991) proposed that in order to understand the differences they and others had observed in the experience of people responding to hypnotic suggestions, investigators need to take into account the active contribution of those persons in seeking out and constructing meaning in the hypnotic situation and their interactions with the hypnotist. In engaging their individual cognitive capacities to construct personal responses to the perceived meaning of suggestions, it was proposed that this active subject attempts "to respond appropriately to suggestions as they are understood within a particular framework, defined by the hypnotist and by the evolving hypnotic relationship" (Sheehan, 1991, pp. 520-521). This focus on how participants might adopt different cognitive processes when responding to the same suggestion and how these choices will be affected by their experience of relevant social and environmental cues (McConkey, 1991) resulted in a new understanding of hypnosis.

These ideas, advanced by Sheehan (1991) and McConkey (1991), were elaborated in different frameworks. Some of these theories combine previous frameworks, concepts, and models, and in doing so, they not only benefit from previous models but also go beyond the combined theories in their scopes. Other theories introduced new elements and insights, besides integrating previous concepts and models, to form new theoretical frameworks. Several of these eclectic theories are discussed below.

2.5.1. *Unified cognitive model*

In their unified cognitive model, Brown and Oakley (2004) built on the response-set and dissociation theories. They outlined different levels of cognitive control based on the contention scheduling theory (see section 2.3.1) and, as per Kirsch (1997), distinguished between hypnotizability and suggestibility (see section 1.4). Notably, the association of hypnotic responses to automaticity governed by the SAS is heavily influenced by theoretical postulations that originated from Woody and Bowers (1994). They defined two styles of responding to hypnotic suggestions. When hypnotized participants respond by directly activating appropriate schemata through contention scheduling without incorporating the SAS, it is labeled concentrative style. In contrast, when hypnotized participants deliberately use their SAS to guide and help contention scheduling in choosing the proper source schema, it is called constructive style. In the authors' eyes, these postulated styles resemble the dissociation and response-set theories, respectively. Brown and Oakley (2004) argued that suggestibility, apart from hypnosis, is related to the constructive style. However, hypnotizability (i.e., increased suggestibility due to hypnotic induction) is more closely aligned with the concentrative style. Notably, "some individuals may adopt one style under some circumstances and another style when the situation changes" (Brown & Oakley, 2004, p. 176).

For the authors of the current review, an ambiguous point is whether these styles refer to states (i.e., temporary modes of operation) or traits (i.e., stable characteristics). It should be noted that the concentrative and constructive styles in Brown and Oakley's (2004) account are incompatible: In the concentrative style, the SAS is inhibited, but in the constructive style, the SAS is heavily utilized. To explain the evidence supporting the two-style hypothesis, the unified cognitive model refers to McConkey et al. (1989), where two high-hypnotizable participants are compared based on behavioral responses and experiential reports: For one, "the suggested effects just happened, but for … [the other] they were created by her cognitive effort" (p. 137). Thus, these styles cannot be used simultaneously by participants but rather are stable, at least during a session where the context is unchanged.

Therefore, based on our understanding, their suggestion allows for three possible specifications. (1) Styles are *induction-related states*. Even though styles of responding are states, they are fixed for a given participant during a given induction but may change in response to another procedure. Which style is used depends on the antecedent factors that can be highly variable. Following this interpretation, one expects that hypnotic suggestibility scales would have low test–retest reliability. However, HGSHS-A scores, for example, are reliable (Piccione et al., 1989). A counterargument against this point is that since the contexts of hypnotizability tests are similar enough, the subjects do not use different procedures when responding to these scales on several different occasions. In contrast, when considering the relation between hypnotizability and other scales, previous studies showed context effects (e.g., Spanos et al., 1989), although some other studies failed to obtain similar results (e.g., Nadon et al., 1991). Nevertheless, one should notice that studies investigating the multifactorial structure of hypnotizability rely on a single session result, and they still indicate that several different capabilities are required for responding to various suggestions (Woody et al., 2005; Zahedi & Sommer, 2022). However, based on our understanding, since the concentrative and constructive styles are dissonant, the unified cognitive account should commit that, within a session, participants can use either constructive or concentrative style. Hence, in this scenario, the theory cannot explain the multifactorial structure of hypnotizability.

(2) Styles are related to *general traits*. That is, there are two distinguishable groups of individuals; one group relies on the constructive and the other on the concentrative style. These differences may originate from discrepancies in cognitive capabilities. In this sense, the unified cognitive theory can explain Terhune et al.'s (2011) observation that there are two groups of high-hypnotizables, one with higher dissociative tendencies and the other with higher imaginative capabilities. Nevertheless, the unified cognitive theory still inherits some issues discussed with regard to the response-set and dissociation theories. For instance, since the SAS is supposed to be disabled in the concentrative style, one expects that some hypnotized participants could not perform executive function tasks at all, which contrasts with published reports (cf. Jamieson & Woody, 2007; Parris, 2017). Further, considering the concentrative style, the unified cognitive theory can only explain enhancements in performing executive function tasks under the influence of suggestions by attributing them to bottom-up processes, which again is at variance with empirical findings (cf. Zahedi et al., 2020b). Additionally, if styles are related to general traits, the unified cognitive model cannot explain the multi-factorial structure of suggestions related to intra-individual differences.

(3) Finally, the constructive style is related to direct verbal suggestions, and the concentrative style is employed for responding to suggestions during hypnosis. If participants exclusively used the concentrative style during hypnosis, they might be responsive to suggestions during hypnosis but not so much when receiving suggestions in a non-hypnotic context. However, hypnotic and direct verbal suggestibility are highly correlated (e.g., Braffman & Kirsch, 1999; Kirsch, 1997).

To discuss the unified cognitive theory, we extrapolated several possible scenarios based on the theory's assumptions. This highlights that, first, more than one account can be deduced based on the theory. Second, for the theory to be useful for experimental hypothesis generation, it should commit to a single scenario; otherwise, it can become too vague to be tested empirically. Based on the previous discussion, only the first and second specifications (i.e., styles are related to *induction-related states or general traits*) are theoretically beneficial, wherein the unified cognitive model goes beyond the response-set and dissociation theories by combining them. Notably, these two scenarios can explain a range of phenomena (e.g., multiple groups of high-hypnotizable participants) that neither theory can explain independently. However, as discussed above, some of the fundamental issues related to these theories pertain to the unified cognitive theory as well.

2.5.2. Three-Dimensional comprehensive theory of hypnosis

Several theories are structurally very similar to the unified cognitive model, and it has been argued that they can accommodate the multifactorial structure of hypnotizability (Sadler & Woody, 2021). We will shortly discuss three such theories, which have stimulated research recently, and argue why they cannot account for the multifactorial structure of hypnotic suggestibility. We start with the comprehensive three-dimensional theory that Barber (1999) proposed.

Barber made several vital theoretical contributions to the field of hypnosis. During his first phase (e.g., Barber, 1969; Barber & Calverley, 1962), he focused more closely on the role of motivation on hypnotic responsiveness, which later was integrated into sociocognitive approaches. Afterward, he focused on fantasy proneness (Wilson & Barber, 1982) as a main variable pertinent to hypnotizability and further developed several scales for measuring imagination and hypnotizability for objectively investigating his hypothesis (Barber & Wilson, 1978). However, although research showed the critical contribution of imagination in hypnotizability (Lynn & Rhue, 1988), a consensus was achieved that imagery does not at least causally determine responsiveness to suggestions (for review, see Lynn et al., 2019; Terhune & Oakley, 2020).

As Barber (2000) discussed, mainly in response to the findings of Barrett (1996) and Pekala et al., 1995 showing that at least some highly hypnotizable participants do not use imagery at all for responding to suggestions, he expanded his earlier theoretical framework, where he considered imagery the main driving mechanism of responsiveness to hypnotic suggestion. In the new framework, Barber (1999) argues that there are three groups of high-hypnotizable participants: fantasy-prone, amnesia-prone, and positive-set (Barber, 1999). The first group uses imagination to respond to suggestions, whereas the second group relies on dissociation. The remaining high-hypnotizable individuals, that is, positive-set participants, are positively motivated to respond but do not possess the "extraordinary" personal characteristics of the other two groups. The mechanisms by which positive-set participants respond to suggestions are explained in more detail by initial iterations of Barber's theory, that is, the task-motivational theory (Barber, 1969; Barber & Wilson, 1977). These mechanisms are affected by antecedent variables such as "attitudes, expectancies, and motivations with respect to the situation, and the wording and tone of instructions-suggestions and of questions used to elicit subjective reports" (Barber, 1969).

Barber's (1999) and (2000) theory, as intended, can explain several types of high-hypnotizable groups. A criticism here is that the theory predicts the existence of three separable groups of highly hypnotizable participants, but the current results indicate that only two groups can be distinguished (Terhune, 2015; Terhune et al., 2011). Nevertheless, in explaining intra-individual differences (i.e., distinguished groups of suggestions, e.g., direct- and challenge-ideomotor), the theory might be less useful. Based on Barber (1999), an individual can either respond by using fantasy or being "positive-set;" nevertheless, in both cases, the participant can respond to all items using that single mechanism. Only theories that assume several non-mutually exclusive processes can explain the multifactorial structure of hypnotic suggestibility. Notably, Barber (2000) discusses four situational factors that will simultaneously affect hypnotic subjects: "(a) the social dimension of hypnosis; (b) the hypnotist's personal efficacy …; (c) the hypnotic induction; and (d) the suggested ideas" (p. 232). However, he maintains that these factors "differentially affect the three different types of highs" (Barber, 2000, p. 232). This argument makes these four factors irrelevant to the separation of several groups of suggestions, as instead of presenting four mechanistically differential factors affecting every suggestion, they affect dissociable groups of hypnotizable participants differentially. In this sense, as the structure of Barber's theory becomes very similar to the unified cognitive model, it also suffers from issues discussed in relation to that model.

2.5.3. Three dimensions of hypnotic depth

The second theory that is structurally similar to the unified cognitive theory is the three dimensions of hypnotic depth (Shor, 1962). Shor's theory is formed in part in response to how goal-directed striving can happen while participants are experiencing an altered state of consciousness (Shor, 1959). Accordingly, he discusses that the altered state of consciousness might be "the relative breakdown of the usual orientation to generalized reality into nonfunctional awareness" (Shor, 1959, p. 601). Later, to better comply with his psychodynamic orientation, Shor (1962) adds another component to the dual-factor explanation of hypnosis: archaic depth. Thus, he argues that hypnotic responsiveness has three dimensions: role-taking, trance depth, and depth of archaic involvement. The first two components are similar to other multifactorial accounts and, therefore, are not discussed here again. The third component, however, is discussed as later it will be the groundstone in formulating the relational theories of hypnosis (see section 2.6). In Shor's words, archaic involvement is related to "the extent to which a special hypnotic 'transference' relationship is formed onto the person of the hypnotist" (Shor, 1962, p. 31). Shor later developed a phenomenological method for empirically investigating the archaic involvement. This method and its successor, such as the experiential analysis technique (Sheehan et al., 1978), provide an additional and better-defined approach for understanding subjective responses to hypnosis, which is missing from standardized hypnotizability scales. However, when one considers specific scales for measuring archaic involvement (Nash & Spinler, 1989; Shor, 1979), it becomes clear why testing and falsifying such an abstract concept might be problematic. For instance, the archaic involvement measure, a 20-item questionnaire (Nash & Spinler, 1989), consists of items that might be better understood in terms of rapport between the hypnotist and the hypnotized individual without assuming transference. Some examples are: "I especially admire the hypnotist" or "I felt that everything that the hypnotists did and said deeply mattered" (Nash & Spinler, 1989).

Regardless of the specific components of the theory, one should ask whether the theory achieves its purpose of explaining hypnotic phenomena. Notably, based on Shor's discussions, none of these dimensions is necessary for responding to suggestions. For instance, obedient-type individuals respond actively; that is, they are high in role-taking but very low on trance depth. Yet sleepy-type individuals respond passively as they are high in trance depth but low in role-taking. Conspicuously, three dimensions of hypnotic depth can explain several types of highly hypnotizable participants but not the existence of several groups of suggestions, as none of the mechanisms discussed are necessary for a specific group of suggestions.

2.5.4. Multifactorial model

The final multicomponent theory we will discuss is the multifactorial model of hypnosis (Evans, 2000). Evans (2000) assumes that the domain of hypnosis is composed of four conceptual factors. These factors are expectations, suggestibility, cognitive distortion (i.e., relaxation, imagery, trance logic), and dissociation. The first component, i.e., expectations, is related to the placebo effect and is "common to any therapeutic modality and has its foundation in the special doctor-patient relationship" (p. 3). Notably, Evans (2000) contends that not only hypnosis but any treatment can induce placebo and that "the placebo response is about 60 % the magnitude of the treatment variable that is being investigated" (p. 3). However, Evans (2000) does not believe that placebo is part of hypnotic phenomena as he argues that "the label hypnosis evokes powerful expectations of change and therapeutic involvement which may be quite independent and possibly unrelated to the changes produced by the essential core of the hypnotic condition" (p. 3).

The second factor of the hypnotic domain, suggestibility, refers to the responsiveness to suggestions made during hypnosis. However, Evans (2000) discusses that suggestibility is irrelevant unless one considers the type of changes in the subjective experience that participants have during responding to suggestions. The change in subjective experience depends on whether cognition, dissociation, or expectation is used to respond to the suggestions. Therefore, based on our understanding, it seems that the suggestion factor is merely a placeholder for the other factors of hypnosis.

The third factor is "the distortions of perception, memory, cognition, and physiology" (p. 8), which can be called cognitive distortion. Evans (2000) discusses the relation between three "cognitive" processes and hypnotic phenomena. The first is relaxation, which he considers not a central part of hypnosis or hypnotic induction in accordance with the contradictory evidence that we discussed in section 2.2. He further argues that mental imagery can be considered relevant to hypnotic phenomena only if imageries can be manipulated voluntarily by participants. And finally, he discusses trance logic, or the ability "to tolerate logical inconsistencies in perception, cognition, physiology, and sensation" (p. 9). Although Evans (2000) describes trance logic as a well-document characteristic of hypnosis, he then mentions that it is not necessarily a cognitive component but "may relate to dissociative experiences of hypnosis" (p. 9).

Finally, the fourth factor of the hypnotic domain is dissociation, which is described as "the core of what is usually considered deep hypnosis" (p. 10). This factor, which Evans (2000) argues is the basis of the ability to move between states of consciousness, has already been covered in section 2.5.2. To summarize, although the multifactorial model attempts to offer a multi-component model for understanding the hypnotic domain, in the end, it focuses, in particular, on absorption and dissociation, which makes the theory very similar to the basic concepts of dissociation theories. Therefore, all strengths and limitations that we discussed with regard to some of the basic versions of dissociation theory (see Section 2.5.2) are still pertinent to this model as well, which we will not repeat here for the sake of brevity.

2.6. Relational theories of hypnosis

The next category of theories that we will review is related to relational theories. We selected two based on our systematic criteria: the social-psychobiological model (Bányai, 1998) and hypnosis, attachment, and oxytocin: an integrative perspective (Zelinka et al., 2014). Since these two theories present incremental differences rather than revolutionary changes, we will discuss them together.

After investigating behavioral and neurophysiological markers of hypnotic interaction in both the hypnotist and the participant for several decades (e.g., Bányai et al., 1985; Varga et al., 2008), Bányai (1998) proposed a relational theory. She argues that hypnosis can only be understood if one considers that "hypnosis develops in a unique interaction between hypnotist and subject, and we should study the interaction itself" (p. 53). This fact is highlighted when considering "similar physiological changes seemed to appear in the hypnotist and subject" (p. 54). For instance, if an active-alert induction process is used (e.g., pedaling a bicycle during the induction process), hypnotists usually experience stiffness in their legs (Banyai & Hilgard, 1976). In other words, hypnosis causes synchrony between the hypnotist and the subject in terms of overt movements, postures, or some covert processes (e.g., breathing and electromyographic activity). These phenomena were usually involuntary and out of awareness" (p. 55–56).

Next, Bányai (1998) notes that hypnotists' styles might be divided into distinct categories: "a physical-organic style and an analytic-cognitive style" (p. 57). Notably, these styles are closely related to transference and countertransference, which are considered to be essential in psychoanalytic approaches for achieving desired treatment effects. Therefore, all "healing" effects of hypnosis can be explained on the basis of the formation of an intimate relation between the hypnotists and the subject that can invigorate unresolved personal issues of the subject and provide a safe place for settling them.

Similar to this idea, Zelinka et al. (2014) contend that to understand the therapeutic effects of hypnosis, one needs to study the attachment style that develops between the caregiver (the hypnotist) and the care seeker (the participant). Based on attachment theories (for review, see Rajecki et al., 2010), four attachment styles can develop between caregivers and care seekers. One style is healthy and improves the developmental perspective of the care seeker (i.e., secure style), and three others are detrimental: anxious-ambivalent, disorganized, and avoidant. Zelinka et al. (2014) argue that "when a therapist fulfills the characteristics of a secure caregiver, the patient may have a relational experience that is healing in its own right" (p. 36). The role of suggestions, especially non-verbal communications similar to unconscious communications introduced by the Ericksonian approach (see Section 2.7), is to instantiate a healthy attachment style. Based on their attachment explanation of hypnotic phenomena, Zelinka et al. (2014) contend that oxytocin, a hormone intensely involved in inter-personal bonding (Feldman & Bakermans-Kranenburg, 2017), mediates the effects of hypnotic suggestions.

However, previous studies refuted the physiological predictions of Zelinka et al. (2014). That is, nasal oxytocin administration will impede responding to (post)hypnotic suggestions (Parris et al., 2014). Further, when Varga and Kekecs (2014) measured pre and post-hypnosis levels of oxytocin, they found a numerical reduction in participants' oxytocin that was not significant. These results are the

exact opposite of what can be deduced from relational theories. However, Bryant et al. (2012) have found nasal oxytocin administration can increase hypnotic responsiveness in low-hypnotizable participants. A point in defense of these theories is that neurotransmitters have complex relations that might be ignored by focusing on only one, and one neurotransmitter might exert different effects depending on the location of the impact (Stahl, 2018). For instance, nasal oxytocin administration might not cause the effects the authors expected due to affecting different locations in the brain, and further oxytocin might be elevated during some periods of hypnosis, followed by reduction afterward due to alterations in other neurotransmitters. The theorists of the relationship theories have recently expanded their empirical focus to include other neurotransmitters for understanding hypnotic phenomena, such as dopamine and serotonin (Katonai et al., 2017), which needs to be integrated into their theories as well.

Wickramasekera (2015) proposed a potentially better approach to understanding the neural effects of relational aspects of hypnosis in the empathic involvement theory. First, they define hypnosis as "an experience of enhanced empathy in which a hypnotic subject utilizes perspective taking, empathic concern, and empathic aspects of [theory of mind]" to experience hypnotic phenomena (p. 343). Afterward, the authors, using a network approach, focused on the interaction between the default mode network, which is involved in phenomenal consciousness (Whitfield-Gabrieli & Ford, 2012), and the mirror neurons, which are involved in imitating others' actions and gestures to understand them (Gobbini et al., 2007; Tognoli et al., 2007). This approach allows for investigating relational aspects of hypnosis in tandem with other effects and phenomena. However, this hypothesis must be tested more vigorously through direct empirical investigations.

In general, although relational theories put an interesting focus on the interactional nature of hypnosis, they are inherently restricted. Previous studies have shown that rapport contributes to participants' responsiveness to suggestions (for review, see Lynn et al., 2019; Lynn et al., 2023). However, rapport is neither essential for being responsive to suggestions, especially for highly suggestible participants (Lynn et al., 1991), nor omnipotent enough to describe all hypnotic phenomena. For instance, although one might claim that different interaction styles (i.e., transference and countertransference) explain the existence of several groups of high-suggestible participants (Terhune, 2015), they cannot explain the multifactorial structure of hypnotizability (see section 1.4). Further, interactional styles alone can neither describe changes in SoA and SoR nor objective changes in perception, cognition, and behavior; after all, it is unheard-of for a person, who experiences an interpersonal relationship with the therapist during psychotherapy, to have hallucinations or experience loss of SoA. Even in conjunction with other variables, such as expectations and cultural influences, they explain only less than half of the variance in suggestibility (Lynn et al., 2019). If one adds other factors to interpersonal theories, such as expectations, placebo, or changes in attentional processes to describe hypnotic phenomena, then these theories will become either a sociocognitive theory or a dissociation one. For this reason, although the interpersonal variable is critical in understanding hypnosis, it should be integrated into other perspectives rather than be the single focus of any model.

2.7. Ericksonian theories

Numerous practical guides and theories of hypnosis are built based on the practice-oriented techniques that Milton H. Erickson pioneered (Lankton, 2020). Before we describe one of these theories, which focuses on ultradian cycles (Rossi, 1982), it is essential to understand the Ericksonian approach itself (for more in-depth discussion, see Lynn & Hallquist, 1990).

In describing his approach, Erickson (1958) emphasizes, "one of the most important of all considerations in inducing hypnotic phenomena is meeting the patient as a personality and his needs as an individual adequately" (p. 7). He argues that too often, "the effort is made to fit the patient to an accepted formal technique of suggestion, rather than adapting the technique to the patient in accord with his actual personality situation" (p. 7). Notably, the Ericksonian approach is intended to be adaptive, and therefore, describing it in some rigid principles is a demanding task. For instance, in describing his naturalistic induction technique, it is mentioned that Erickson engages in a prolonged discussion with the patients until they show signs of readiness when a direct or indirect suggestion is sufficient to induce the so-called therapeutic trance (Lankton, 2020; Rossi, 1982).

Erickson understands hypnosis as an altered state of consciousness where multimodal imagery (e.g., visual, auditory, kinesthetic, etc.) can have therapeutic effects. The healing influence of hypnotic suggestions stems from the fact that they can facilitate unconscious insight into personal issues and promote finding unique and individualized pathways for resolving them by searching unconscious materials (Erickson, 1958; Erickson & Rossi, 1977). These insightful imageries, which "depotentiate" habitual patterns that block one from experiencing needed feelings, thoughts, or behavior, can be induced using flexible and personalized metaphors, stories, and suggestions. However, the approach focuses on hows rather than whys. In other words, the Ericksonian approach is a group of clinically informed and oriented techniques to induce healing effects in patients (Lynn & Hallquist, 1990), which is minimally concerned with why these effects are caused.

The ultradian theory of hypnosis is an attempt to fill this gap. Rossi (1982) first explains that besides circadian cycles, which are physical, mental, and behavioral changes that follow a 24-hour cycle, there are shorter 90 to 100-minute cycles called ultradian rhythms. These shorter cycles are "an endogenous oscillation of the central nervous system" (p. 23) that organizes critical physiological and behavioral responses. These responses range from drowsiness to muscle tonicity and social behaviors. Hypnosis, as an altered state of consciousness, is also aligned with these natural rhythms and facilitated in a specific phase of them, which explains why Erickson's naturalistic induction technique is effective. Erickson would engage his patients in a discussion until they reached the point in their ultradian cycle where they could experience a trance (i.e., hypnotic responsiveness). This state, which is called a common everyday trance, is experienced regardless of hypnosis. For instance, "the student with a faraway look in his eyes during the middle of a lecture, and the driver who automatically reaches his destination with no memory of the details of his route" are experiencing this altered state of consciousness (Rossi, 1982, p. 22). When Erickson detected this state in his patient, he nudged the patient into "a state of response attentiveness through his interesting stories, momentary surprises, fascinating facts, and so forth" (Rossi, 1982, p. 23).

One of the characteristics of this trance state is literalism, which can be defined as an exact reception of ideas without an elaboration of them in terms of implied or associated meanings (Erickson & Rossi, 1976; Green et al., 1990). However, this state of consciousness characterized by "reduced foci of attention" does not necessarily relate to "hyper-suggestibility" (Erickson & Rossi, 1976). Instead, it is better understood if one considers that at each point, there are two levels of communication: conscious and unconscious. The conscious level searches for general meanings and does not attend to literal associations that are sent to the unconscious level. Therefore, the basic idea of the Ericksonian approach is to "utilize a general context to fixate the attention of consciousness while the individual associations of words, phrases, or sentences within that context [would be] registered in the unconscious where they can work their effects" (Erickson & Rossi, 1976, p. 167).

In evaluating the hypotheses of the Ericksonian approach in general, one should note that contrary to Erickson's assumption, high hypnotic responsiveness (i.e., trance) is not characterized by responding literally (Green et al., 1990; McCue & McCue, 1988). Further, as discussed in regard to conditioning and dissociation theories, the assumption of trance creates more unanswered questions instead of explaining hypnotic phenomena.

Additionally, there are several other issues pertinent to the ultradian theory. First, although Rossi (1982) discusses that there might be several different and unsynchronized ultradian cycles, he maintains that these cycles are 90–100 min, which explains the normal Ericksonian hypnosis duration. New studies, however, show that ultradian rhythms are aperiodic with varying durations ranging from a few minutes to a few hours (Goh et al., 2019). Even if the ultradian cycles were fixed and not aperiodic, based on our understanding, the assumption that trance happens based on a periodic biological clock predicts variable hypnotizability based on the time of testing subjects. However, research has not documented that hypnotic responses covary with any ultradian rhythm. Contrary to this hypothesis, studies showed a high test–retest reliability regarding hypnotizability scores over 10, 15, and 25 years (Piccione et al., 1989), which should not be expected if one expected a causal relation between ultradian cycles and hypnotizability. Finally, the assumption of such a mechanism as the driver of hypnotic phenomena reduces them to bottom-up physiological responses rather than explaining them in terms of top-down cognitive processes, which again is not in accordance with the literature (Terhune et al., 2017).

Some of Erickson's innovative and ingenious techniques (e.g., reframing and paradoxical interventions) have links with contemporary research in clinical, cognitive, and social psychology (Lynn & Hallquist, 1990). Furthermore, the surge of interest in Erickson's creative techniques reignited the historical fascination with hypnosis as a transcendent methodology, which highlights the general heuristic value and contribution of the Ericksonian approach.

2.8. *Cold control theory*

The cold control theory of Dienes and Perner (2007) is one of the most active hypnosis theories and has inspired substantial research. Cold control theory accounts for changes in the subjective SoA during hypnosis by focusing on ascriptive metacognition, which emphasizes the judgment of agency, differentiating it from other forms of metacognition that focus on the judgment of performance (Dienes et al., 2012; Miele et al., 2011). Based on the higher-order thought model (Rosenthal, 2002; Rosenthal, 2006), Dienes and Perner (2007) distinguished first-order thoughts from second and third-order thoughts. First-order thoughts refer to the awareness of sensations (e.g., I see a black cat). Second-order thoughts refer to the consciousness of being aware of sensations (I know that I see a black cat). Third-order thoughts designate the consciousness of being conscious of sensations (I am aware of knowing that I see a black cat). Dienes and Perner (2007) contended that hypnosis does not affect first-order thoughts (perception and cognition) but may render second and third-order thoughts dysfunctional and inaccurate. Further, they assumed that highly hypnotizable participants can bypass both second- and third-order thoughts, whereas medium-hypnotizable participants are only capable of bypassing third-order thoughts.

Dienes and Hutton (2013) suggested that ascriptive metacognition is related to the left DLPFC (e.g., Miele et al., 2011), which implies that the dysfunctionality of higher-order thoughts during hypnosis is due to the disruption of left-DLPFC activity. Dienes and Hutton (2013) showed that low-frequency repetitive transcranial magnetic stimulation (rTMS) of left-DLPFC, compared to rTMS of sensory and motor cortices (control condition), increased responsiveness to some hypnotic suggestions. Because four out of five tested suggestions were related to motor actions, differences between the stimulation conditions might have been due to decreased responsiveness in the control condition, where sensory and motor cortices were stimulated. Several replication attempts yielded inconsistent results. Coltheart et al. (2018) found that rTMS of left-DLPFC did not affect any hypnotic measure, but rTMS of right-DLPFC enhanced hypnotizability. Perri et al. (2022) compared hypnotizability before and after transcranial direct current stimulation (tDCS) over bilateral DLPFC with the anode over the left hemisphere. Although hypnotizability was enhanced in the experimental compared to the sham group, it is unclear whether the enhancements were due to decreased activity of left or increased activity of right-DLPFC.

Arguing that "impairment of frontal function would enhance hypnotic response in virtue of the role of the frontal lobes in metacognition" (p. 1083), Semmens-Wheeler et al. (2013) investigated the effects of alcohol consumption on responsiveness to hypnotic suggestions. They found that alcohol increased subjective responsiveness. However, an alternative interpretation is that alcohol in lower doses can attenuate fear responses and stress by affecting limbic and visual brain regions (Gilman et al., 2008), which lowers restraint and facilitates alterations of SoA. Conclusions are further limited by the absence of alterations in objective responsiveness. Therefore, after consuming alcohol, participants might have been less able to judge their SoA rather than being truly more suggestible.

An important finding related to the cold control theory comes from investigations of trait metacognition in high-hypnotizables. Terhune and Hedman (2017) used a task assessing judgment of agency (Metcalfe et al., 2012) in which participants selected target stimuli with a mouse cursor while avoiding other stimuli that moved across the monitor. By manipulating cursor lag, the researchers showed that although the judgment of performance in high-hypnotizables was equivalent to other participants, their SoA was less affected by cursor lag, purportedly reflecting decreased metacognition. A caveat is that Terhune and Hedman (2017) used short cursor

lags (i.e., 50 and 100 ms) compared to studies of SoA in schizophrenic patients with the same task (i.e., 250 ms and 500 ms; Metcalfe et al., 2012). However, their results generally support that highly hypnotizable individuals show diminished judgment of agency.

Other studies targeted self-monitoring. Lush et al. (2016) employed Libet et al.'s (1983) task to measure the time of conscious awareness of the intention to act. They argued that "highly hypnotizable people, on the one hand, and meditators, on the other, lie at two ends of a spectrum of metacognition" (p. 2). Their results confirmed that, compared to meditators, high-hypnotizables were less able to self-monitor their actions (shown by delayed awareness of the intention to act). Notably, the authors measured self-monitoring, which has been shown repeatedly to be positively related to cognitive functioning and executive functions (Roebers, 2017; Roebers & Feurer, 2016). According to this reading, if the authors expect that self-monitoring is disrupted in high-hypnotizables, they should also expect that top-down executive functions are disrupted. However, in another study, Lush et al. (2020) argued that "response to imaginative suggestion involves the top-down voluntary control of action and experience … according to a stable trait ability [of hypnotizability]" (p. 2). Yet imaginative suggestions administered in the hypnotic and non-hypnotic contexts typically elicit comparable feelings of involuntariness (Kirsch et al., 2008, Study 2; Meyer & Lynn, 2011) and objective reactions (Braffman & Kirsch, 1999). Hence, in our opinion, if responding to imaginative suggestions requires "the top-down voluntary control of actions," then it is difficult to advocate that the hypnotic-suggestion-induced responses are due to the disruption of self-monitoring, as Lush et al. (2016) suggested.

Palfi et al. (2021) argue that a positive effect of posthypnotic suggestions on executive function tasks "calls into question the key statement of the [cold control] theory, as it suggests that high[-hypnotizable individuals] can acquire abilities through hypnosis that they do not possess when responding non-hypnotically" (p. 219–220). Their repeated-measured design compared no-suggestion, non-hypnotic instruction, and posthypnotic suggestion conditions. In the non-hypnotic instruction and posthypnotic suggestion conditions, elaborations of the standard Stroop task instructions were presented as direct verbal suggestions. They found that non-hypnotic instruction and posthypnotic suggestion both enhanced behavior compared to the no-suggestion (i.e., baseline) condition. The authors concluded that participants do not perform better in response to hypnotic suggestions. However, the non-hypnotic instruction of Palfi et al. (2021) closely resembled a direct verbal non-hypnotic suggestion. In another study, the authors argue that similar cognitive mechanisms are engaged in response to suggestions "…within a range of contexts and [even] in response to indirect or implicit suggestion" (Lush et al., 2020, p. 5). Therefore, in our opinion, a more reasonable interpretation of Palfi et al. (2021) might be that hypnotic and non-hypnotic suggestions *can similarly* enhance performance, which, as the authors discussed, refutes the cold-control theory. If direct verbal suggestions (hypnotic and non-hypnotic) did not enhance performance, there should have been no difference between the suggestion (hypnotic or non-hypnotic) and the baseline. The replicated fact that direct verbal suggestions in both hypnotic (Landry et al., 2021; Lifshitz et al., 2013; Zahedi et al., 2019; Zahedi et al., 2020b) and non-hypnotic conditions alike (Parris & Dienes, 2013), can enhance performance in cognitive tasks is replicated. However, Palfi et al. (2021) interpretation of these results

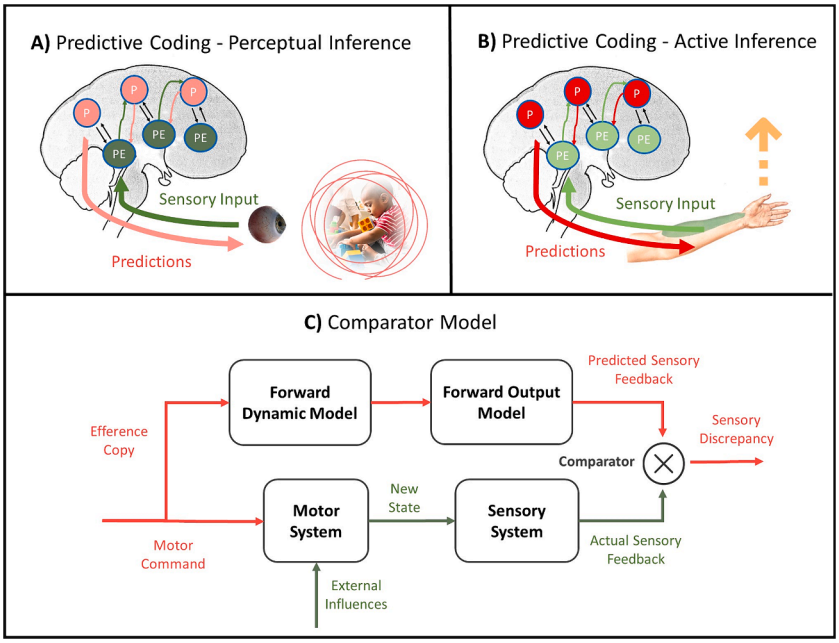


Fig. 1. Schematic representations of (A) perceiving stimuli (e.g., kids playing), which requires perceptual inference, and (B) actively and voluntarily moving (e.g., raising hand and arm), which requires active inference, as suggested by the predictive coding model. "P" refers to predictions, and "PE" to prediction errors; notably, there are multiple layers where prediction and prediction errors interact. In perceptual inference (Friston, 2010; Yon et al., 2019), the PEs are more precise (i.e., having higher weight) than Ps, shown with pale versus dark colors, respectively. In contrast, in active inference, Ps are more precise than PEs (Adams et al., 2013; Yon et al., 2019), shown with dark versus bright colors, respectively. (C) Schematic representation of the comparator model (Frith et al., 2000).

appears questionable.

Several other issues with the cold control theory are worth considering. As the cold control theory assumes a single cognitive mechanism underlying hypnosis, it cannot address individual differences in hypnotizability besides attributing them to suggestion difficulty (see section 1.4). Further, to explain the existence of several groups of high-hypnotizable participants (see section 1.4), Dienes et al. (2016) discuss that "one possibility is that there are two ways of implementing cold control—the mindless and the mindful" (p. 26). However, previous studies have shown that mindfulness is strongly related to metacognition (Jankowski & Holas, 2014; Norman, 2017). Therefore, in our opinion, a critical question is how a group of highly hypnotizable participants, who, according to the cold control theory, have impaired metacognition, can be mindful.

Further, the cold control theory assumes that disruption of higher-order thoughts is necessary for alterations in the subjective SoA. Positive responses to suggestions are highly but not perfectly correlated with the experience of involuntariness (Bowers et al., 1988). In our understanding, if a theory assumes that hypnosis is "solely a metacognitive phenomenon," it should commit that either hypnosis induces a state where higher-order thoughts are disrupted or that the disruption of higher-order thoughts is a trait of high-hypnotizable individuals. In the state hypothesis, one should expect a significant difference between non-hypnotic and hypnotic suggestibility. This prediction, however, is refuted by many observations (Braffman & Kirsch, 1999; Kirsch, 1997; Parris & Dienes, 2013). Alternatively, if proneness to disruption of higher-order thoughts is considered a trait, then different wordings of suggestions should exert little effect on SoA during hypnosis, as higher-order thoughts are disrupted in any case. As discussed above, there is no consistent evidence supporting this prediction (Lynn et al., 1987; Matthews et al., 1985; Spanos, 1971).

Considering the explicit assumption of the cold control theory that "impairment of frontal function would enhance hypnotic response in virtue of the role of the frontal lobes in metacognition" (Semmens-Wheeler et al., 2013, p. 1083) and also that disruption of the DLPC facilitates hypnotic responsiveness, it is appropriate to consider neural evidence. The disruption of higher-order thoughts cannot explain some neural observations. Several studies have shown that when cognitive tasks are performed during hypnosis, brain activity in the lateral prefrontal cortex (LPFC) and DLPFC increases (Cojan et al., 2013; Cojan et al., 2009) or at least does not decrease (Egner et al., 2005). Even apart from hypnosis, high-hypnotizables have evidenced higher LPFC activity than low-hypnotizables during flanker tasks (Cojan et al., 2015) and increased frontal activity (as indicated by a larger frontocentral P300 amplitude in ERPs) during an oddball task (Kirenskaya et al., 2019). Notably, when neurophysiological activity associated with cognitive performance on specific tasks is increased under an experimental condition, the underlying resources are more engaged. This increased engagement possibly indicates that (I) the experimental condition can directly increase activity in that region. Alternatively, one can hypothesize that (II) some aspect supporting the operation of those resources is less available in the experimental condition, and therefore, these neurophysiological resources should work harder albeit less efficiently. None of these two explanations will align with the cold control theory's hypothesis.

Finally, the PFC and especially DLPFC are essential regions in the executive function network (Miyake & Friedman, 2012; Niendam et al., 2012; Rottschy et al., 2012; Wager & Smith, 2003). For example, based on a meta-analysis (Smith et al., 2016), the connectivity of DLPFC with other brain regions plays a critical role in cognitive control. Therefore, based on the hypotheses of the cold control theory that disruption of DLPFC by rTMS or disruption of the frontal lobe by consuming alcohol can enhance hypnotic responsiveness – as we understand it – one should assume that at least the disruption of some cognitive control mechanisms will not diminish hypnotic responsiveness. However, there seems to be no evidence that high- and low-hypnotizable individuals perform differently in different executive function tasks, either outside of hypnosis (Dienes et al., 2009) or while experiencing task-irrelevant hypnotic suggestions (Egner et al., 2005; Zahedi et al., 2017). Still, some studies show that high hypnotizables have better working memory and executive functions (Faerman & Spiegel, 2021), but others have observed that high hypnotizables perform worse in cognitive tasks (Jamieson & Sheehan, 2004).

2.9. Discrepancy attribution theory

Drawing on the selective construction and preservation of experience theory (SCAPE) and its corollary discrepancy attribution hypothesis (Whittlesea, 2002a), Barnier and Mitchell (2005) suggested that these principles can explain hypnotic phenomena (Barnier et al., 2008). In the SCAPE theory, developed to explain memory processes, Whittlesea (2002a) distinguished production processes (i.e., percepts, cognitions, overt actions) and their evaluation. During remembering events, one engages in different levels of cognitive and perceptual processing and simultaneously evaluates these processes. The evaluation can tag a process as coherent, incongruent, or discrepant. The experience of coherency arises when all aspects of the current experience are congruent. In contrast, errors in current processes, that is, when one aspect is incongruent with others, would engender a sensation of incongruity that will stop the processing. The sensation of discrepancy arises when one aspect of an event is surprisingly fit (or unfit) with other aspects, and the surprise cannot be attributed to the event. The experience of discrepancy will instigate a search for a plausible source, such as past experiences, the agent's current state, or some event characteristics. For example, when participants encounter pronounceable nonwords constructed by changing one letter of real words, the ease of pronunciation of them is discrepant with their meaninglessness. This discrepancy is resolved by (falsely) attributing these words to a list of previously encountered words (Whittlesea, 2002a, 2002b).

Barnier and Mitchell (2005) assumed that the cognitive and perceptual processes used to produce responses are the same during and outside of hypnosis. However, Barnier and Mitchell (2005) contend that production processes occur marginally easier during hypnosis, a fluency that engenders surprise. Based on the discrepancy hypothesis, people who experience hypnosis will falsely attribute this fluency to the characteristics of the event and their own state. In other words, they will attribute the experienced fluency to the involuntariness of their response or being controlled by the hypnotist (Barnier et al., 2008).

Why should responses be more fluent during hypnosis? Barnier and Mitchell (2005) suggested that this is due to (1) a positive

motivation to be a good subject and (2) the special characteristics of hypnotic settings that promote relaxation and concentration. Further, the discrepancy attribution theory explains variance in hypnotizability across participants by assuming that some participants may be either more capable of focusing during hypnosis or more sensitive to discrepancy than others. Both cases would facilitate the experience of discrepancy and the attribution of this discrepancy to involuntariness.

In evaluating the discrepancy attribution theory, the first question is whether responding to suggestions is more fluent during hypnosis than expected. If so, this expectation is unlikely to derive from comparing hypnotic versus mundane responses because hypnotic responses are usually marked by interruptions, hesitation, and slowness (e.g., Frith et al., 2000; Martin & Pacherie, 2019). One can suggest that participants who have negative hypnosis expectancies consider even a degraded response as fluent. However, negative hypnosis expectations are correlated with lower hypnotizability and unresponsiveness to hypnotic suggestions (Green & Lynn, 2011; Jones & Spanos, 1982; Lynn et al., 2019; Lynn et al., 1984). Accordingly, one should paradoxically expect low-hypnotizables to experience a stronger feeling of fluency and be more hypnotizable, which shows that the basic assumptions of the theory can cause a theoretical conundrum.

Second, does hypnotic induction engender more focused attention or self-awareness, as Barnier and Mitchell (2005) suggested? According to Terhune and Cardeña (2010), hypnotic induction does not necessarily increase attention or self-awareness. Further, hypnotic suggestions may even trigger imaginings that contradict the suggestion and still bring about the expected responses (Zamansky & Clark, 1986). Notably, attention to behavior usually impairs production processes rather than making them more fluent or easier (Brown et al., 2013; Clark, 2013; Custers & Aarts, 2010). Finally, high-hypnotizables do not differ from low-hypnotizables in attentional capabilities (Dienes et al., 2009) or sensitivity to discrepancy, as evident in their judgments of agency (Terhune & Hedman, 2017). Therefore, the basic assumptions of the discrepancy theory are inconsistent with research findings that would provide support for key theoretical propositions.

2.10. Predictive coding models

The predictive coding approach has gained prominence in several fields and has recently been applied to hypnosis. The predictive brain model (Fig. 1A, B), also called the Bayesian brain or predictive coding model (for review, see Yon et al., 2019), postulates that the brain acts like a scientist trying to understand the world via Bayesian-type modeling. Bayesian systems involve three integral elements: priors (i.e., epistemological uncertainty), evidence, and posteriors (i.e., updated epistemological uncertainty). In the predictive coding model, priors are top-down predictions (i.e., efferent signals) formed based on our cognitive or heuristic models. These predictions constantly interact with exteroceptive (including somatosensory), proprioceptive, and interoceptive evidence (i.e., afferent signals). Through these interactions, posteriors are formed, which are updated versions of priors created by considering the probability of the priors given the evidence (Clark, 2013).

The free-energy principle holds that "any living or non-living self-organizing system that resides at equilibrium with its environment must minimize its free energy" (Friston, 2010, p. 127). Free energy refers to the surprise an organism experiences when collecting data contradictory to the predictions. Combining the free energy principle and the predictive coding model, if a prediction error arises (i.e., being in a surprised state), the system tries to return to a stable condition where prediction errors are resolved. This can be achieved by active inference or perceptual inference. Perceptual inference (Clark, 2013) refers to situations where prediction errors are eradicated by updating priors. In other words, by changing the cognitive model based on which predictions are formed, predictions become aligned with sensory feedback (Fig. 1A), which results in perceptions.

Alternatively, active inference refers to conditions where prediction errors are eliminated by modifying actions to align outcomes with predictions (Clark, 2013; Friston, 2010; Yon et al., 2019). During active inference (Fig. 1B), top-down predictions (descending proprioceptive predictions) are formed and sent to target muscles through cortico-cortical and corticospinal projections. Here, prediction errors (i.e., afferent signals) are used in reflex arcs to correct the action and match it with predictions. Prediction errors are gradually downregulated in a process called sensory attenuation, and their projection beyond thalamic gates is severely reduced. Therefore, prediction errors are not integrated into the system beyond reflex arcs (Brown et al., 2013; Yon et al., 2019). For example, when an agent wants to grasp a glass of water, a prediction is made about the following location of the hand. Since, in the beginning, the hand is still in its original location, there will be a disparity between the prediction and sensory feedback. Based on the free energy principle, the agent tries to reduce the error signal. Here, the disparity is eliminated by active inference: Sensory feedback is used in reflex arcs to correct the hand position. When sensory feedback reaches thalamic gates, it is downregulated through sensory attenuation. As the agent's hand starts to move based on the prediction, the disparity between the prediction and sensory feedback is resolved.

One of the essential concepts in the predictive coding model is that efferent signals sent through descending projections are predictions and not motor commands (Adams et al., 2013). In contrast, based on the comparator model (Blakemore et al., 2003; Frith et al., 2000), a predecessor of the predictive coding model (Fig. 1C), motor commands are sent to muscles. In the comparator model, an efference copy of the motor commands shapes a forward dynamic and a forward output model. For instance, when a person is engaged in a physical action (moving the hand to grasp a glass of water), an efferent copy of the motor command is used to build a forward dynamic model, which is a prediction about the next state of the system. This prediction will be compared to the desired state (if I move my hand with velocity Y in direction X, I should reach and grasp the glass at time Z). Then, based on the causal representation of the motor system, the system forms a forward output model, which predicts the sensory input to be received if the motor system acts in that particular way (Miall & Wolpert, 1996). The production of the forward dynamic and output models are based on the operator's knowledge about the system's behavior and are compared continuously with proprioceptive signals. If disparities arise between the forward output model and the actual sensory feedback (hand is in position Z instead of X), then the behavior (i.e., hand movement) will

be modified to diminish the discrepancy. In contrast to the comparator model, there are no motor commands in the predictive coding model, and the only descending signals are predictions. Hence, the necessity for postulating the existence of an efference copy of motor command for producing forward dynamic and output models is eliminated. For a more detailed account of precision, precision weighting, and gain of prediction errors in prediction updating, the readers can consult (Hohwy, 2013). The predictive coding model has been employed in two very different theories of hypnosis to explain changes in the subjective SoA.

2.10.1. Interoceptive predictive coding

Jamieson (2016) was the first to apply the predictive coding theory to hypnotic phenomena. In his theory, called the interoceptive predictive coding theory, Jamieson (2016) attempts to explain hypnosis and some other techniques, such as meditation, in a unified theory. The idea of explaining hypnosis along with meditation has deep roots and was first proposed by Davidson and Goleman (1977). In their model, named "a psychobiological perspective on transformation of consciousness," Davidson and Goleman (1977) contend that hypnosis, like meditation, evokes an altered state of consciousness. Interoceptive predictive coding, however, extends both the basic state approach and the decoupling account based on Blakemore et al. (2003). Blakemore et al. (2003) used hypnosis to investigate the neural underpinnings of misattributing movements to alien sources in different psychological and mental disorders, such as delusion of control in schizophrenia. Their experiment had three conditions: (1) Participants should move their hand actively by themselves. (2) They should notice their hand being moved by a mechanical device. Finally, (3) they were informed that their hand was moved by the device, but in reality, the device was inactive. The third condition resembles the common hand levitation suggestion. After receiving these suggestions, the participants' hands moved upward in all conditions. From the results of the third condition, Blakemore et al. (2003) concluded that participants must have formed appropriate motor commands and a functioning forward dynamic model. By using positron emission tomography (PET), Blakemore et al. (2003) observed that hand levitation in Condition 3 was correlated with increased glucose metabolism in the parietal cortex and cerebellum. They suggested that the increased activity indicates the deactivation of the forward output model, causing a persistent, unresolved error signal, which caused participants to misattribute their actions to an external source.

Jamieson (2016) reframed the results of Blakemore et al. (2003) into a predictive coding model. He argued that several studies had shown that during hypnotic suggestions, both blocking a movement (i.e., hypnotic paralysis) or inducing a movement (e.g., hand-levitation) disrupt the connection between the frontal cortex and the parietocerebellar network (e.g., Cojan et al., 2009; Deeley et al., 2013; Walsh et al., 2015). Consequently, hypnotic-suggestion-induced actions are governed by different processes compared to standard actions. Further, Jamieson (2016) argued that the results of Blakemore et al. (2003) suggest that hypnotized participants cannot perceive the source of their actions because their forward output model is disrupted "at the point of source or at the points of transmission and terminus" (Jamieson, 2016; p. 320). As the neural motor network consists of highly divergent pathways, the possible point of disruption must be at the source. Jamieson (2016) concluded that the misattribution of movements to external sources in hypnotized participants must be related to the formation of internal models based on the hypnotist's suggestions. Further, these internal models are not implemented through normal pathways but by lower-level perceptual and proprioceptive units.

Therefore, proprioceptive forward models (predictions) will not be formed, and due to their absence, participants cannot recognize the source of their actions. In a new iteration of his theory, Jamieson (2016) further explains that during hypnotic responses, the suggested generative models cannot be updated based on feedback from reality, as doing so will align those generative models with reality. Since salient prediction errors will otherwise have a higher weight compared to predictions, allostatic processes are recruited to minimize interoceptive prediction errors, stabilising interoceptive predictions (Barrett & Simmons, 2015), which in turn down regulates the gain of salient prediction errors so that they do not engage attentional, cognitive, and perceptual processes, which would nullify the alterations in SoA and SoR experienced by hypnotized subjects (Kihlstrom, 2008; Orne, 1959).

Evidently, Jamieson (2016) utilized a mixture of the comparator and predictive coding models. As he later mentioned, "the proposal by Jamieson involves a mix of the computational comparator and the active inference models of motor control" (Jamieson, 2021, p. 7). This mixed model is a feature of earlier interoceptive predictive coding accounts (Seth et al., 2011), where it is proposed that the representation of self-related emotional and motivational states relies on comparing interoceptive predictions and interoceptive prediction errors. The comparator resides in the anterior insula, and interoceptive errors are formed based on the unconscious state of the body representations, originating from the posterior insula, and the conscious representation of the state of the body originating from the mid insula (Craig, 2009). However, in a fully predictive coding model (Clark, 2013; Friston, 2010), only predictions and not motor commands are formed and sent through downward projections (Adams et al., 2013). Therefore, in predictive coding architecture, no efference copy of motor commands can be generated, rendering the comparator model inapplicable. Following Jamieson's (2016) account, if forward models fail to be generated during hypnotic motor suggestions, then a fully consistent predictive processing account might expect no action at all.

One might say that Jamieson's (2016) proposition strictly refers to higher-order predictions. For instance, he mentions: "The orchestration of control during hypnotic motor suggestions has shifted from motor intentions in PFC to spatial-body representations in posterior parietal cortex" (Jamieson, 2021, p. 6). In the predictive coding model, the higher-order predictions are amodal (e.g., I want to grab the glass of water). As the predictions propagate downward, they will become more specific and modally defined (e.g., limb X should move in direction Y) (Clark, 2013; Friston, 2012; Hoffmann & Falkenstein, 2012). To resolve this issue, Jamieson (2018) discusses a fluid balance between the two processes at hand when responding to hypnotic suggestions: first, participants should exert a response, and therefore, there should be at least a form of downward propagation of predictions. This downward prediction will originate from the hypnotic suggestions and be relayed through the anterior insula. Simultaneously, (interoceptive) prediction error minimization, which happens in the posterior and mid insula, prevents the general generative model of participants from being updated, and hence, the altered SoA and SoR can be maintained while responding to suggestions (Jamieson, 2018, 2021). He further

argues that due to the suppression of interoceptive prediction errors in lower levels of predictive hierarchy, salience network and executive control network responses can be suppressed while attentional responses can be maintained. This proposition then extends the theory's reach beyond ideomotor responses and can be applied to other forms of suggestions (Jamieson, 2021), aligning it more closely with previously discussed dissociation theories.

Accordingly, two theoretical complications arise from Jamieson's interoceptive predictive coding account. The first theoretical byproduct of the hypothesis that participants will have modal predictions without forming high-order amodal ones is that one should assume full-fledged information segregation, for instance, between frontal and parietal brain systems. Otherwise, the propagation of prediction errors to upper layers (i.e., via the anterior insula), where there are no predictions, should disrupt the system completely. This assumption, however, is unattainable given the basic assumptions of the predictive coding model (Beni, 2022; Hipolito & Kirchhoff, 2019). That is, a fundamental assumption of the predictive coding and free energy principle is bidirectional communication and transmission of information between layers (Friston, 2010, 2012). Second, attributing actions and events to internal versus external states involves higher-order interpretations. This statement can be understood better if one considers the predictive coding account of positive symptoms in patients with schizophrenia (Dima et al., 2012; Kirihara et al., 2020). The current understanding is that unresolved lower-level prediction errors are propagated to higher layers, which will force patients with schizophrenia to use unconventional and bizarre explanations to justify their prediction errors (Fletcher & Frith, 2009). The higher-order regions, including the frontal lobe, play an essential role in forming delusional beliefs and hallucinations. Together, although the interoceptive model is aspiring in nature and domain, as it goes beyond strict predictive coding framework by combining it with other frameworks, it should address two issues: first, a mechanistic description of the proposed processes that involve predictions, prediction errors, and their interaction should be added for all layers involved. Second, the issue of information segregation should be addressed.

Finally, Jamieson's (2016) claims regarding changes in frontal lobe functioning and its connectivity with other brain areas during hypnosis are nuanced, and existing evidence is mixed regarding the theory's predictions (for a review of changes in frontal lobe functioning during hypnosis, see Parris, 2017). For instance, McGeown et al. (2009) showed a decrease in default mode activity, which included anterior cingulate, inferior, medial, and superior frontal gyri, in highly but not low-hypnotizable participants when they are resting during hypnosis (i.e., not responding to any suggestions). However, when participants were responding to a perceptual suggestion, these differences were not observed. Further, Jiang et al. (2017) showed that although the connection between the insula and DLPFC is increased during hypnosis, the connectivity of DLPFC and the default mode network is decreased. Even though the anterior, mid, and posterior compartments of the insula were not segregated, one might suggest that the results are aligned with Jamieson (2021). However, multiple studies have shown increased rather than decreased frontal lobe activity during hypnotic-suggestion-induced actions and enhanced functional connectivity between the frontal lobe and some parts of the parietal lobe, which might be contradictory to the theory's predictions (e.g., Cojan et al., 2013; Cojan et al., 2009; Ludwig et al., 2015; Pyka et al., 2011). But again, one should consider that connectivity between different areas might be affected differently based on whether one is considering faster, high-frequency connectivity or slower, low-frequency one (Jamieson & Burgess, 2014). Together, more research is needed to address the predictions that Jamieson (2016) delineated.

The interoceptive coding model cannot explain several aspects of hypnotic phenomena. If only one mechanism is necessary for responding to suggestions, the factorial and typological structure of hypnotizability scores (see section 1.4) cannot be explained. Further, if the effects of suggestions are attributed to disruption of communication between the frontal and parietal lobes, one cannot explain the enhancement of performance in cognitive tasks due to task-relevant posthypnotic suggestions (see section 1.2). Nevertheless, the initiative to explain hypnotic phenomena by considering psychological and mental diseases, such as schizophrenia, is a significant contribution. Additionally, Jamieson (2016) is the first researcher to summarize existing findings from the perspective of predictive coding and free energy, which we suggest is crucial to understanding hypnosis.

2.10.2. New predictive coding model

Martin and Pacherie (2019) advanced a second application of predictive coding by expanding the concept of sensory attenuation in active inference (Brown et al., 2013). Focusing on motor suggestions, Martin and Pacherie (2019) proposed that, in contrast to active inference under normal conditions, during hypnotic-suggestion-induced actions, somatosensory and proprioceptive signals are not downregulated. Instead, they are incorporated into the system even beyond reflex arches and thalamic gates. Further, during hypnosis, somatosensory feedback is even more precise compared to normal conditions and given a higher weight in the (Bayesian) model. However, if predictions do not have a higher weight compared to prediction errors, there will be no action. Hence, the predictions will also be more precise compared to normal conditions because, during hypnosis, predictions are based on hypnotic suggestions. This scenario is related neither to the standard perceptual nor active inference. In normal conditions, during active inference, somatosensory feedback is downregulated and given a lower weight than predictions, and during perceptual inference, somatosensory feedback is given higher weight than predictions. In contrast, during hypnosis, in a fast altering manner, the precise predictions will be given a higher and then lower weight compared to prediction errors. As both predictions and somatosensory feedback are precise, a persistent and unresolved prediction error is generated. To interpret strong prediction error signals during hypnosis, participants will attribute their actions to external forces rather than self-generated volition. Further, as the relative weight of predictions and prediction errors will change periodically in the course of the hypnotic transaction, the commonly observed phenomenon that hypnotic responses are hesitant and slow can be explained.

Although the new predictive coding's account appears to be very plausible, it cannot explain at least four sets of observations. First, one of its central tenets is that predictions are more precise during hypnosis as they are based on the hypnotist's suggestions. However, the literature shows that suggestions might only provide an amodal prediction (e.g., event *Y* will happen). This amodal suggestion is turned into modal predictions (e.g., for event *Y* to happen, *X* and *Z* should happen) by participants and based on their existing heuristic

models, expectancies, and interpretations. For instance, replicating and expanding Winkel et al. (2006), Galea et al. (2010) investigated the physiological effects of hypnotic paralysis. They asked high-hypnotizable participants to feel rigidity and stiffness in their arms and then asked them to move their hands with the implication that it could not be done. In response, participants seemed to use widely divergent strategies. Some (1) *simultaneously activated agonist and antagonist* muscles (biceps and triceps), others (2) *only activated the antagonist* but inactivated the agonist, and still, some others (3) *did not activate any muscle* group. Thus, participants individually formulate unique and different modal predictions based on the same amodal suggestion. Therefore, the precision of these uniquely formulated predictions could not be reinforced by the hypnotist's words blind to these modal predictions. This fact contrasts with the claim of Martin and Pacherie (2019) that predictions are more precise during hypnosis because the hypnotist's words reinforce them.

Second, Martin and Pacherie (2019) contended that the hypnotic context plays an essential role, leading participants to "pay very close attention to what is going on internally and especially to their body when motor suggestions are administered" (p. 137). However, hypnotic induction does not necessarily increase attention or self-awareness (Terhune & Cardeña, 2010). Furthermore, many studies have shown that, although induction can have a significant effect, direct verbal suggestions have very similar effects across different hypnotic and non-hypnotic contexts (Braffman & Kirsch, 1999). This fact questions the tenet of the new predictive coding model that during hypnosis, prediction errors are more precise due to "a particularly low level of noise" in the hypnotic context.

Third, the predictive coding model states that suggestion difficulty "would depend on the level of sensory evidence provided by the suggested event, and interindividual differences would result from interindividual differences in the "ability" to assign more or less weight to one['s] prior expectations" (p. 147). Based on our understanding, this postulation can neither explain intra- nor inter-individual differences in responding to hypnotic suggestions as it attributes individual differences to the difficulty of items (see section 1.4).

Fourth, as Martin and Pacherie's (2019) primary focus is on motor suggestions, their account does not readily transfer to other phenomena. For example: (I) the authors noted that in suggestions calling for hallucinations, participants seem to have sensory input from an imaginary source, which has high precision and further "because the sensory quality of the mental image, through attention, is gaining in precision there is a potential match between these predictions and the current sensory evidence" (Martin & Pacherie, 2019, p. 144). If their theory assumes the possibility of a stream of bottom-up signals originating from the memory (similar to Barron et al., 2020), why does the same process not govern motor suggestions? During motor suggestions, feedback from imaginary stimuli might also be given higher weight than feedback from the external world, and prediction errors could be formed based on imaginary stimuli rather than actual sensory feedback (similar to what is suggested by Zahedi et al., 2024). On the other hand, if they assume that mental imagery creates a top-down signal from memory (similar to predictions), then how does perceptual inference happen during responses to hallucinatory suggestions when the predictions are more precise than prediction errors?

(II) One of the most reliable observations in the field of hypnosis is the effectiveness of pain-reducing suggestions (for review, see Thompson et al., 2019). Since Martin and Pacherie (2019) contended that the hypnotic context leads participants to "pay very close attention to what is going on internally and especially to their body when motor suggestions are administered" (p. 137), then one might confer that they expect the attention would be heightened during responding to hypnotic analgesia as well. If so, they should address how hypnotic analgesia can happen when participants' attention to noxious stimuli is increased.

(III) As discussed in section 1.2, another robust hypnotic phenomenon is that posthypnotic suggestions can help hypnotized participants learn new trigger-response or action-outcome contingencies (Lifshitz et al., 2013; Lindelov et al., 2017; Zahedi et al., 2019). However, according to our understanding of the theory, the new predictive coding account does not try to explain this observation.

(IV) Martin and Pacherie (2019) expected that training with direct verbal suggestions before hypnosis would decrease the sense of involuntariness during hypnosis. However, Gorassini and Spanos (1986) have shown that when participants practice with suggestions included in the Carleton University Responsiveness to Suggestion Scale (Spanos et al., 1983), their "objective-involuntariness" (which reflects"the number of suggestions that were objectively passed and experienced as at least moderately involuntary" (Gorassini & Spanos, 1986, p. 1006)) can be increased; noteworthy, the increase is observed if practice is accompanied by seeing a model successfully responding to suggestions or receiving information about cognitive strategies that can be used for responding to suggestions. One might argue that Martin and Pacherie (2019) will refer to passive training with direct verbal suggestions, and therefore, their hypothesis is aligned with the results of Gorassini and Spanos (1986). Further, repeated exposures to the same hypnosis scale can produce decrements in responsiveness, probably due to less engagement (Fassler et al., 2008; Meyer & Lynn, 2011), which might be aligned with the new predictive coding framework.

3. Summary and Conclusions

In the current investigation, we reviewed prominent theories of hypnosis selected on the basis of a systematic search of the literature (Table 1). No theory can remain relevant and intrinsically valuable if it does not engage in the process of refinement. Accordingly, our analysis aims to encourage theoretical advancements by highlighting (I) the assumptions that can be tested, modified, or clarified, (II) the possibility of expanding the theory to account for additional hypnotic phenomena not considered in the initial formulation, and (III) the importance of restructuring by adding constructs or eliminating those that do not align with or contradict empirical findings.

Until recently, two broad perspectives dominated contemporary theories of hypnosis, namely, the state and sociocognitive approaches. As discussed in detail, the state view construes hypnosis as an altered state of consciousness, referred to by some as a "trance" (Elkins et al., 2015; Revonsuo et al., 2009). This altered state of consciousness is characterized variously by increased concentration and absorption, dissociation from aspects of the self and the surroundings, and increased suggestibility and responsiveness (Elkins

et al., 2015; Gruzelier, 2005; Kallio & Revonsuo, 2003; Kihlstrom, 2005). In contrast, the sociocognitive approach eschews the conceptualization of hypnosis as a special state of consciousness. Instead, it emphasizes certain fundamental and mundane cognitive processes or contents as antecedents of hypnotic responses that work alongside the potent social context of hypnosis (Barber, 1999; Chaves, 1997; Lynn & Green, 2011; Sarbin, 1950; Spanos, 1971). However, since Lynn and Rhue's (1991) compendium on hypnosis theories, the allure of this dichotomy has faded. As Jensen et al. (2015) commented, describing existing theories as dichotomous gives a false account of the literature. The current review not only agrees with this statement but provides evidence for a spectrum of theories, many of which only partially overlap (if at all) with these traditional dichotomous accounts of hypnosis (see also Kirsch & Lynn, 1995).

It is conspicuous that considerable agreement exists across theoretical frameworks (Lynn et al., 2020). Three vital areas of consensus are: (I) Hypnotic suggestions can produce profound alterations in subjective experiences that cannot be reduced to relaxation. This argument does not, however, mean that hypnosis is not associated with relaxation, as evidently, inducing relaxation is one of the mainstream clinical applications of hypnosis (Edmonston, 1991). (II) These changes are generally not faked or reflect mere compliance. This fact is noticeable when considering the sense of conviction in hypnotic responses, which is closely related to an altered SoR. (III) Participants often experience decreases in SoA during hypnosis, yet they can resist and even oppose suggestions. Finally, (IV) personality differences, such as openness and neuroticism, do not adequately account for individual differences in hypnotic responsiveness (Green, 2004; Nordenstrom et al., 2002). In our opinion, it is vital to highlight and expand these areas of accord in future versions of theoretical accounts of hypnosis.

An intriguing point regarding the range of existing theories of hypnosis will be revealed when one compares the current review with Lynn and Rhue (1991). Conspicuously, there are several new theoretical additions to the field, such as the unified cognitive model, discrepancy attribution theory, cold control theory, and predictive coding theories. Further, almost all theories that were covered by previous systematic theoretical reviews (Lynn & Rhue, 1991; Sheehan & Perry, 1976) have been updated and changed significantly, as evident by the newer iterations discussed in the current review. Nevertheless, almost all novel theories have borrowed from previous theories either by combining them (e.g., the unified cognitive model) or by reframing their main conceptual core, such as the new predictive coding model that focuses on attention. This encouraging point reveals that theoretical contributions that might be discarded based on a set of observations still might contribute to our understanding of hypnosis, at least conceptually.

For future development of theories, several other points should be considered. Many theories cover a range of phenomena but do not or only partially account for others. The assumptions of other hypnosis theories, whether borrowed from cognitive theories or original, are at variance with empirical evidence in a number of respects. One of the most common problems is the concentration of some theories on motor movement suggestions and the accompanying involuntariness to the exclusion of other phenomena. For example, two critical observations are hardly touched by the theoretical frameworks reviewed here.

(1) Independent of difficulty levels, researchers have identified qualitatively different categories of suggestions (e.g., McConkey et al., 1980; Oakman & Woody, 1996; Piesbergen & Peter, 2006; Woody et al., 2005; Zahedi & Sommer, 2022) and multiple sub-groups of high-hypnotizable participants (Acunzo & Terhune, 2021; Reshetnikov & Terhune, 2022; Terhune et al., 2010). However, none of the reviewed theories presents a plausible account for the existence of multiple suggestibilities and typologies. For any theory to be able to account for the multifactorial structure of hypnotizability, it should assume several mechanisms (e.g., cognitive functions). Each mechanism should be critically required to respond to at least one group of suggestions, but the mechanisms should not be mutually exclusive so that they might be used simultaneously (Zahedi & Sommer, 2022). Finally, even though using a basic level of each mechanism would be a prerequisite, a provision should be implemented to allow for the use of these functions in different combinations by different groups, which will then justify multiple groups of highly hypnotizable participants (Reshetnikov & Terhune, 2022).

(2) Performance enhancements in cognitive tasks due to task-relevant hypnotic and posthypnotic suggestions is one of the hottest topics in the field (Landry et al., 2021; Lifshitz et al., 2013; Perri et al., 2020a; Zahedi et al., 2020b). However, only the decoupling theory attempts to explain why and how task-relevant suggestions can improve performance, and still, the offered explanation is at odds with certain current observations (c.f., Zahedi et al., 2020b). Notably, the concept of enhancement due to hypnotic and posthypnotic suggestions has been investigated thoroughly regarding physical exercise. Some innovative studies have shown that positive "motivation" might be, if not the only, the most important factor that causes enhancement in those tasks (London & Fuhrer, 1961, p. 322). Regardless of criticisms that apply to the London-Fuhrer design, such as problems with baseline measures, contradictory suggestions, and negligence of sense of convictions (for a more detailed discussion, see Sheehan & Perry, 1976), the conclusion of the physical enhancements cannot be generalized to cognitive enhancements. The main reason is that, although for physical enhancements, mere motivation to perform better might be enough, positive motivations might fall short when it comes to cognitive tasks, for instance, in the case of the Stroop task (MacLeod, 1991). We do not argue that motivation is unnecessary, but we suggest that motivation should be augmented with a cognitive mechanism, such as mental practice through imagery to become effective. Nevertheless, the previous studies reveal how vital it is not to generalize the results of a study without considering the situation, hypnotizability of participants, and emotional/motivational components of the suggestions used (Sheehan & Perry, 1976).

Consequently, we suggest that existing theories be revised in a way that they provide a plausible explanation for all existing empirical findings and not just a subset thereof. We strongly think this is impossible without taking into account the multi-component and possibly bifactorial structure of hypnotizability (McConkey et al., 1980; Woody et al., 2005; Zahedi & Sommer, 2022) and, therefore, suggest that existing theories accommodate such an assumption. However, we do not exclude the possibility of different structural propositions that can accommodate existing empirical findings.

The second purpose of any substantial theory is to offer refutable hypotheses that can fuel attempts for conjectures or refutations (Popper, 1971). In this way, the loop between empirical and theoretical research can be closed fruitfully. We argue that due to advancements in neuroimaging techniques, it is imperative to have testable neural hypotheses alongside behavioral ones. Although

current theories of hypnosis usually try to explain observed phenomena, very few commit to specific hypotheses, such as testable behavioral or neural outcomes. The lack of testable hypotheses hampers the integration of data into models and has created unresolvable rivalries between different theories to the extent that some (Halligan & Oakley, 2013; Oakley & Halligan, 2009; Spanos, 1986) suggested eschewing novel theoretical and empirical attempts to understand hypnotic phenomena themselves (i.e., intrinsic research), and instead using suggestions for understanding other cognitive phenomena (i.e., extrinsic research). In our eyes, this approach is of limited value since if it is unclear what mechanisms drive the effects of suggestions, how can they be used to address open questions in cognitive neuroscience?

Although not a necessary criterion for evaluating a scientific theory, an issue with hypnosis theories is their surprising isolation from clinical ramifications and their focus on neurocognitive processes. Only a few theories explicitly discuss clinical implications, such as neo-dissociation, response-set, psychoanalytic, and Ericksonian theories. This shortcoming in hypnosis theories limits their potential reach and relevance to clinical practice. However, many of the most critical and intriguing hypnotic phenomena are related to clinical applications, such as pain reduction (Thompson et al., 2019), weight control (Milling et al., 2018; Zahedi et al., 2020a; Zahedi et al., 2023), smoking cessation (Lynn et al., 2010), and cognitive enhancements (Lindelov et al., 2017; Zahedi et al., 2020b). The discussion of clinical implications can motivate active practitioners to deploy insight from the hypnosis theories in their practice (e.g., Capafons, 2004; Lynn & Kirsch, 2006; Wagstaff et al., 2010), which will benefit both researchers and clinicians since it enhances current practices and provides new empirical data for future theoretical endeavors.

Another area that requires immediate attention is revising extant scales of hypnotizability, which were often developed more than five decades ago and are no longer optimal instruments to capture and assess diverse theoretical perspectives and facilitate empirical research. Researchers have critiqued scales for their loss of essential information (e.g., concrete sub-scales), binary scoring, single trial sampling, sub-optimal suggestion content, and vague suggestion wording (Acunzo & Terhune, 2021; Kallio, 2021; Zahedi & Sommer, 2022). Given our previous recommendation for having testable and refutable hypotheses, especially regarding the factorial and typological structure of hypnotizability, we argue it is also vital to have appropriate instruments to investigate those hypotheses.

Although all theories reviewed here have the potential to develop further and contribute to the field by offering empirical hypotheses and theoretical insights, several groups of theories have a special potential for shaping the future of the field. First, eclectic approaches such as multifactorial approaches (e.g., Barber, 1999; Brown & Oakley, 2004) not only combine the sociocognitive and dissociation theories but, through doing so, can cover a range of issues inaccessible to original theories. Further, due to the current advancements in neuroimaging techniques, combining behavioral explanations and neural ones is critical to offer a comprehensive neurobehavioral framework (Halligan & Oakley, 2013; Jensen et al., 2017; Oakley, 2012). Some approaches, such as predictive coding theories (Jamieson, 2021; Martin & Pacherie, 2019) and those that integrate predictive coding in their future iterations (e.g., Lynn et al., 2023) have a better position of addressing neural questions based on the current understanding in the field of cognitive neuroscience. However, for all current theories, it is a necessity to engage in theoretical development to be useful in providing further hypotheses for empirical investigations and a more robust understanding of the hypnotic phenomena that help clinicians and researchers alike.

In conclusion, we evaluated the most prominent theories of hypnosis systematically based on objective criteria. The review highlights the salient strengths, limitations, and heuristic values of different theoretical perspectives. Further, the review pointed out shortcomings of existing theories in understanding the domain of hypnotic phenomena in its entirety in order to indicate the importance and necessity of revisiting current theories of hypnosis to enhance their adequacy and fertility and the value of formulating novel hypnosis theories. We also provided practical and concrete suggestions on how these shortcomings might be resolved and how the empirical, clinical, and theoretical endeavors can engage in mutually beneficial communication. It should be noted, however, that these suggestions are not the only way forward, and theorists might find creative ways to go beyond the current issues and shortcomings. We hope the current review foments meaningful discussions that spur advancements in conceptualizing, researching, and applying hypnosis.

CRediT authorship contribution statement

Anoushiravan Zahedi: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Funding acquisition, Conceptualization. **Steven Jay Lynn:** Writing – review & editing, Writing – original draft, Methodology. **Werner Sommer:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2024.103730.

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