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The interaction between language and consciousness

Author names:

Charlène Aubinet,[1,2,3] MSc PhD, Olivia Gosseries,[1,2] MSc PhD & Steve Majerus,[3] MSc PhD.

Affiliations:

[1] Coma Science Group, GIGA-Consciousness, GIGA Institute, University of Liège, Belgium

[2] NeuroRehab & Consciousness Clinic, Neurology Department, University Hospital of Liège, Belgium

[3] Psychology and Neuroscience of Cognition Research Unit, University of Liège, Belgium

Corresponding author:

Name: C. AUBINET

Mailing address: caubinet@uliege.be

Address: CHU de Liège, GIGA Institute (B34, +1), Avenue de l'Hôpital 1, 4000 Liège, Belgium

Telephone number: +32 4 284 36 12

https://orcid.org/0000-0001-5095-5583

Abstract:

The degree of interaction between language and consciousness is a theoretically significant yet poorly understood question. In this review, we examine neuroimaging, cognitive, and neuropsychological studies that address this issue by distinguishing between different aspects or dimensions of language and consciousness. The reviewed studies indicate that high-level semantic and sentence integration occur only in higher consciousness state and under conscious processing conditions, while lower-level phonetic, phonological or lexico-semantic processes appear to remain functional even in the absence of consciousness. We also highlight parallel recovery trajectories between aspects of language and states of consciousness, along with experimental and clinical evidence suggesting that language processing may, in some cases, influence consciousness content or even precede the reemergence of a consciousness state. Evidence of associations between language processing and higher-order conscious thought is further described. Finally, we discuss the theoretical implications and methodological challenges involved in studying and interpreting the interaction between language and consciousness, with particular attention to causal direction and to the possibility that observed associations reflect broader disruptions of integration rather than language-specific mechanisms only.

Keywords:

Consciousness, language, inner speech, unconscious processing, aphasia, brain injury.

1. Introduction

Most of us would agree that one can be conscious in the absence of language as evidenced by non-verbal forms of consciousness for emotions, sensations, or perceptions. Accordingly, many current consciousness theories do not consider language as one of the key determining factors, and refer to it only vaguely as a tool for reporting the content of conscious thoughts (Budson et al., 2022; Graziano et al., 2020; Gross, 2018; Hermann et al., 2022; Mashour et al., 2020; Naccache, 2018; Seth and Bayne, 2022). Language processing is most frequently viewed as a function or consequence of consciousness, like other behaviors such as motor actions (Figure 1A).

[INSERT FIGURE 1 AROUND HERE]

On the other hand, work in the field of philosophy of mind and language considers language as a tool for organizing and expressing thoughts (Sapir, 1929; Whorf, 1956), having led some authors to argue that language may also play a role in shaping human consciousness (e.g., Dennett, 2017; Frankland and Greene, 2020; Miguens, 2022; Miller, 2022; O'Neill, 2015). A close association between the emergence of consciousness and the development of language in human culture has been proposed by the *Communication Hypothesis,* which considers that the communicative function of language is the basis for consciousness (Fedotov and Baidyuk, 2023; Miguens, 2022) (Figure 1B). In the same vein, the recent *Higher Order Language and Inner Speech To "I" Consciousness (HOLISTIC)* neurobiological model (Skipper, 2022) argues that language (especially inner speech) helps generate and maintain higher-order consciousness (i.e., self-awareness and meta-self-awareness) and influence primary conscious experience (Figure 1C). This is in line with previous views suggesting that primary consciousness exists in animals, whereas the emergence of syntax-based language in humans enabled reference to

internal representations and, consequently, higher-order awareness of one's own conscious states (Edelman et al., 2011).

The difficulty of disentangling the role of language in consciousness stems from the multi-determined nature of language processing itself, which ranges from low-level processing of phonetic and phonological features associated with speech to high-level processing of semantic content and morphosyntactic rules involving integration skills (Kovacs, 2021; Mudrik et al., 2014). A similar comment can, however, also be made for the concept of consciousness (Figure 2), which involves different quantitative levels or states (i.e., 'global state of arousal' such as sleep or coma) (Mashour, 2024) and different qualitative types of content (i.e., specific mental representations or information) and subjective experience (i.e., qualia, like 'the taste of a coffee' or 'the experience of redness') (Block, 1995; Laureys, 2005; Overgaard and Overgaard, 2010).

The absence of a clear ground truth for consciousness further complicates investigations into how it interacts with language processing, highlighting the need for caution in interpreting results. For instance, higher-order, reflective conscious thought (including self-awareness and metacognition) is considered by *Higher-Order Theories* to be a defining feature of, or at least closely related to, the phenomenon of consciousness (Brown et al., 2019; Lau and Rosenthal, 2011; Morin, 2006). Likewise, the *Integrated Information Theory* (Tononi et al., 2016) posits that consciousness depends on a system's capacity to generate integrated information. From this perspective, findings reporting associations between language (particularly at its highest levels requiring semantic integration) and consciousness disruptions may simply reflect broader deficits in integration rather than a language-specific role.

[INSERT FIGURE 2 AROUND HERE]

We will examine studies that have investigated the interaction between language and consciousness by focusing on the following questions: (1) Which aspects of language remain functional in states of reduced consciousness? (2) Do consciousness and language recover in a parallel or in a dissociated manner after severe brain injury? (3) Which aspects of language imply conscious processing and (4) which influence conscious experience? (5) How does higher-order conscious thought interact with language processing?

2. Language processing and consciousness state in sleep and anesthesia

By provoking reversible states of unconsciousness, sleep and anesthesia can both be considered as valuable windows into consciousness (Bonhomme et al., 2019; Huang et al., 2018; Mashour et al., 2020; Tononi et al., 2024). Graded consciousness states are associated with different sleep stages, from light (N1 and N2) to deep (N3; i.e., slow-wave sleep) non-rapid eye movements (non-REM) sleep (Tagliazucchi et al., 2013), as well as to the depth of anesthesia (Mashour, 2024).

A number of studies suggest that lexico-semantic processing can occur in light (Andrillon et al., 2016) and even deep sleep (Palma and Titone, 2021; Ruch and Henke, 2020), i.e., in the absence of conscious processing. Some studies have investigated the sleeping brain's capacity to process different aspects of language. In a first electroencephalography (EEG) study, syllables, words, phrases, and sentences were arranged within speech sequences in such a manner that each type of linguistic unit was repeated at distinct frequencies (Makov et al., 2017), allowing for neural tracking of each type. Neural tracking of acoustic units was comparable across wakefulness and sleep. In contrast, neural tracking of higher-level types of information, such as words, phrases and sentences, was only observed during wakefulness. Similar results were

recently obtained by Fogel and colleagues (2022) who used an fMRI synchronization-based approach to examine responses to a movie narrative in awake and asleep participants. In wakefulness, the activation of auditory and frontoparietal networks was synchronized with the following of a high-level narrative plot. Same frontoparietal activity as in wakefulness was also observed during REM sleep in one participant, and partially in one other, but such higher-level processing was not observed in light and deep non-REM sleep. Auditory network activation associated with the narrative was observed in all sleep stages, demonstrating preservation of low-level auditory processing, even in deep sleep. In sum, whereas acoustic processing is relatively preserved during sleep, signs of processing of higher-level aspects of language do not appear to be observable in non-REM sleep stages.

Another fMRI study showed similar results by presenting the same movie narrative during deep anesthesia (Naci et al., 2018). In the non-sedated control condition, significant brain activity was observed in both primary and association auditory cortices, as well as in the frontoparietal cortex, while it was limited mainly to the auditory cortex in deep anesthesia. These results suggest that narrative processing was preserved in the sensory areas, but almost entirely abolished in the frontoparietal regions considered to be associated with integrated, conscious processing. In line with this, Krom and colleagues (2020) investigated anesthesia-induced loss of consciousness using intracranial EEG responses to auditory stimuli including words. They showed that neuronal spiking was largely attenuated in frontoparietal regions upon loss of consciousness, and that auditory processing was restricted to the primary auditory cortex during anesthesia.

The studies reviewed here indicate an absence of integrated processing of verbal information at semantic and morphosyntactic levels in deep sleep and anesthesia, when consciousness state

is strongly reduced or absent. However, sleep and anesthesia do not only alter consciousness, but they exert a broader impact on cognitive processing and behavior, making it difficult to specifically interpret the results in terms of interrelations between language processing and consciousness state only.

3. Language and consciousness state after coma

We will now examine the pathways of recovery of consciousness and language processing in patients suffering from severe acquired brain injury. Whereas comatose patients are fully unawake with no conscious behaviors, patients in a vegetative state (i.e., unresponsive wakefulness syndrome; UWS) have regained wakefulness but remain unresponsive at the bedside, while patients in a minimally conscious state (MCS) show progressive recovery of conscious behaviors (Giacino et al., 2002; Laureys et al., 2010). Importantly, a subcategorization of the MCS has been proposed based on the absence (MCS-) or presence (MCS+) of language-related signs of consciousness such as command following or word production (Bruno et al., 2011; Thibaut et al., 2019), while the recovery of reliable communication (and object use) skills indicates emergence from the MCS (Giacino et al., 2004). Neural responses to verbal commands are also increasingly examined in patients with disorders of consciousness, having led to new labels like the cognitive-motor dissociation (Bodien et al., 2024; Claassen et al., 2024; Egbebike et al., 2022) or covert cortical processing (Edlow et al., 2021; Young et al., 2024). In these conditions, explicit (i.e., cortically-driven responses to verbal commands) or implicit (i.e., cortically-driven responses to language stimuli) processing of verbal information can be detected despite the absence of command following at bedside (Aubinet et al., 2022).

The recovery of voluntary language abilities after coma appears to be in line, or shortly preceded, by the progressive recovery of consciousness. Accordingly, studies in patients with disorders of consciousness have revealed that the proportion of patients reacting to language stimuli increases from low (i.e., UWS) to high states of consciousness (i.e., MCS and emergence from the MCS) (Aubinet et al., 2022). Moreover, Gui and colleagues (2020) showed that EEG-derived neural signals of language processing, including both speech-tracking responses and temporal dynamics of global brain states, go in hand with the type of behavioral diagnosis of impaired consciousness state. As language stimuli become more complex (i.e., from words to entire sentences), associated neural signals become more reliable in differentiating UWS from MCS patients (Gui et al., 2020). Phrase- and sentence-level responses decrease in MCS (relative to healthy controls) but fully disappear in UWS, suggesting no preservation of higher-level linguistic processing once consciousness is fully lost. Altogether, these results suggest an association between the complexity of language processing and consciousness state: the more complex the linguistic stimuli to which the patients respond, the higher their consciousness state (Figure 3). However, these results do not inform us about the causal nature and direction of these associations.

[INSERT FIGURE 3 AROUND HERE]

Regarding the question of causality, it has been shown that residual language-related responses after coma can predict the patients' recovery of consciousness (Claassen et al., 2019; Egbebike et al., 2022; Formisano et al., 2019; Gui et al., 2020; Llorens et al., 2024; Sokoliuk et al., 2021; Steppacher et al., 2020). For example, Sokoliuk and colleagues (2021) recorded EEG brain activity in acute patients who failed to obey commands. They were presented streams of isochronous monosyllabic words that could be parsed into meaningful phrases and sentences.

The results showed a significant correlation between functional outcomes at 3- and 6-months and the strength of the patients' acute neural tracking of phrases and sentences as quantified by inter-trial phase coherence. According to these data, not only does language - or the processes it requires - reappear in line with consciousness state in post-comatose patients, but the recovery of language and related processes may anticipate, and even predict, the reemergence of a consciousness state.

4. Cognitive research on conscious and unconscious language processing

In this section, we will examine cognitive behavioral studies in awake human participants that have examined the type of linguistic units that can be processed in conscious vs. unconscious experimental setups. These studies address the subjective experience of linguistic content, thereby exploring the interaction between language and the qualitative aspects of consciousness.

4.1. Unconscious language processing

4.1.1. Word-level processing

Some cognitive studies using behavioral paradigms, often coupled with EEG, have provided evidence for unconscious semantic processing at the word level (Mudrik and Deouell, 2022). Negative evoked-related potentials (ERPs) at 400 ms (i.e., N400 effect) associated with semantic processing have been observed in EEG studies even for not consciously experienced target words in an attentional blink paradigm (Giesbrecht et al., 2007; Luck et al., 1996). This paradigm classically involves presentation of a rapid stream of visual stimuli, in which the

detection of an initial target prevents the detection of subsequent targets occurring up to 400-600 ms later (Weller et al., 2019).

Rivalry-based paradigms such as the flash suppression paradigm (where a visual stimulus is rendered unconscious by another stimulus presented in a 'flash' to the other eye) (Nakamura and Kawabata, 2018; Wilke et al., 2003) or the binocular rivalry paradigm (where two different stimuli are separately presented to each retina and conscious experience fluctuates between them) have led to more nuanced behavioral results. Chien and colleagues (2023) recently analyzed priming effects based on different levels of semantic associations: (1) direct associations with semantically congruent (e.g., *Glacier-Chill*) or incongruent (e.g., *Freeze-Fire*) prime-target word pairs; (2) cross-form associations including prime words semantically congruent or incongruent with target pictures; (3) metaphoric associations, where prime words were metaphorically congruent (e.g., *Freeze-Heartless*) or incongruent (e.g., *Freeze-Sanguine*) with target words referring to personality traits. Participants were asked to categorize the meaning of the target words as referring to coldness or warmth dimensions. When the primes were rendered invisible using the continuous flash suppression paradigm, no semantic priming effect (i.e., no shorter response times for congruent compared to incongruent trials) was found for the cross-form and metaphoric associations. To be processed, these higher-level semantic associations would thus need to be consciously processed. Priming for direct associations was, however, observed, suggesting that lower-level categorical semantic processing can occur in the absence of conscious perception.

Similar results have been observed with liminal-prime paradigms, where perceptual awareness of the prime is measured on every trial, for example using a scale ranging from 0 ('I saw nothing at all') to 3 ('I saw the prime clearly'). Using this method in a digit categorization task (i.e., 'X is

higher or lower than five'), a study examined the role of conscious perception for the occurrence of priming effects involving either semantic associations (using digit symbols as primes and congruent or incongruent digit words as targets) or perceptual associations (using digit symbols both as primes and targets) (Avneon and Lamy, 2019). Results showed perceptual priming effects independently of the conscious perception of the primes, whereas the semantic priming effect was smaller for stimuli with a low perceptual awareness rating. Comparable results were observed in categorization tasks involving animal names or ambiguous written stimuli (e.g., a symbol interpretable as either "B" or "13"), highlighting that unconscious semantic processing is task-dependent and restricted to categorical contexts rather than extending to broader semantic integration (Biderman et al., 2020; Micher and Lamy, 2023).

In sum, these different studies suggest that low-level, direct semantic associations can be processed for unconsciously perceived stimuli. However, the semantic processing effects will be less marked than for consciously perceived stimuli. Furthermore, conscious perception appears to be necessary for higher-level semantic processing of information. In other words, the more consciously we perceive a stimulus, the more deeply it can be processed semantically.

4.1.2. Sentence-level processing

Several theories of consciousness argue that sentence processing would require consciousness, because sentence processing involves the use of working memory and controlled inferential operations, particularly for more complex sentences (Rabagliati et al., 2018). In a behavioral priming study, Berkovitch and Dehaene (2019) investigated the processing of different syntactic features using subliminal masking paradigms. Based on the participants' response times across five experiments, subliminal priming could be induced by grammatical

category and number as well as by syntactic context, highlighting unconscious processing of some of the syntactic features that characterize sentences.

Other studies have also used EEG measures to investigate semantic and sentence integration in subliminal masking paradigms (Mongelli et al., 2019; Nakamura et al., 2018; van Gaal et al., 2014). In one study, two masked words (a modifier, *not* or *very,* and an adjective, *good* or *bad*) were followed by a visible target noun (*peace* or *murder*) (van Gaal et al., 2014). Participants judged the valence of the target noun in contextually consistent (*very bad-murder*) or inconsistent (*not bad-murder*) three-word combinations. EEG recordings indicated that grammatical negation could occur partially unconsciously, as evidenced by similar occipito-parietal N400 effects for both conscious and unconscious inconsistent sequences. This suggests that unconscious negation can automatically reverse the meaning of an unconscious adjective. However, a more recent study using a word(s)-picture matching task failed to identify an N400 effect for the unconscious processing of short sentences (e.g., *Man pushes woman* as a prime) (Mongelli et al., 2019). Additionally, in another study where entire sentences were rendered invisible through repeated masking of successive words (i.e., six-word sequences including a noun phrase, three adverbs, and a visible target verb), unconscious trials showed a reduced N400 magnitude and extent, which appeared only for the integration of closed subject-verb structures (Nakamura et al., 2018). These results align with Mudrik and Deouell (2022), stating that evidence for the unconscious integration of more than two individual elements (i.e., either words or other non-linguistic objects) remains scarce. They suggest that high-level sentence processing may not be possible for unconsciously perceived information.

To summarize, the results of this section reviewing behavioral cognitive studies in awake participants seem to converge with the neuroimaging studies of the previous section in sedated

or sleeping participants: whereas unconscious processing of auditory and low-level semantic information appears to be possible, higher-level integration of semantic information such as in a sentence context requires conscious processing of the information. These data imply a role for conscious processing in higher-level aspects of receptive language, or in the broader integrative processes that underlie such language operations, supporting claims by Mudrik and colleagues (2014) on information integration (see section 6.3). In the next section, we consider the reverse relationship by examining the potential influence of language processing on consciousness content.

4.2. Influence of language processing on the content of consciousness

The content of consciousness refers to mental representations associated to specific subjective experience that can be decomposed into *connectedness* (i.e., connection and responsiveness to the environment) and *internal awareness* (Martial et al., 2020; Figure 2). We subjectively experience language events produced by others (e.g., an experience of connectedness) but we may also experience internal language-related conscious content in the form of inner speech (Fernyhough and Borghi, 2023). Connectedness content may be experimentally approached by classical conscious perception paradigms for visual (Eiserbeck et al., 2022; Klink, et al., 2013; Sklar et al., 2021), auditory (Eklund et al., 2021, 2019), tactile (Grund et al., 2021; Schröder et al., 2021) or language stimuli (Avneon and Lamy, 2019; Chien et al., 2023) as listed in Table 1. Various methodological approaches have also been proposed to investigate internal awareness content, including questionnaires, experience sampling (i.e., assessment of mind-wandering at random time points), dual-task designs (with a secondary task preventing inner speech) as well as neuroimaging techniques (Alderson-Day and Fernyhough, 2015).

290 [INSERT TABLE 1 AROUND HERE]

291 A number of these studies have demonstrated that language processing at the lexico-semantic
292 level may impact the content of conscious perception or connectedness. Research by Lupyan
293 and colleagues (Lupyan et al., 2020; Lupyan and Ward, 2013) has provided compelling evidence
294 for the influence of language on perception, particularly in the domains of visual recognition,
295 discrimination, and detection. In one study, they explored whether verbal labels affect the
296 detection of visually suppressed objects (Lupyan and Ward, 2013). Using continuous flash
297 suppression, they showed that valid labels enhanced detection accuracy and response speed,
298 whereas invalid labels had the opposite effect. Moreover, Fugate and colleagues (2020) used a
299 control (i.e., 'public', 'belief') or an emotion word (i.e., 'sad', 'angry', 'happy', 'calm') as a semantic
300 prime, followed by two (congruent vs. incongruent) emotional faces presented under binocular
301 rivalry to participants, who were instructed to continually indicate the left- or right-oriented
302 gradient they saw. The authors showed that emotion word priming led to reports of perceiving
303 the word-congruent emotional face for a longer duration, relative to control word priming. In
304 other terms, the presentation of these words changed the time during which emotional faces
305 were maintained in visual awareness. These findings suggest that verbal content may modulate
306 early steps of conscious visual perception (Fugate et al., 2020; Pinto et al., 2015). The influence
307 of semantic activation on conscious awareness of visual objects has also been examined using
308 the attentional blink paradigm (Weller et al., 2019). In that study, targets presented during the
309 inattentional phase could nevertheless be detected more easily when they were objects with
310 learnt semantic content relative to objects with no such content.

311 Secondly, some studies have focused on the contribution of inner speech to the internal
312 awareness component of consciousness (Martial et al., 2020). For example, Bastian and

colleagues (2017) investigated the number of spontaneous reports of mind-wandering during a verbal working memory task, by manipulating the ease at which inner speech could be mobilized. Inner speech was either reduced using an articulatory suppression task (i.e., continuously repeating 'a-b-c' aloud) or enhanced using the presentation of written verbal material, based on the assumption that silent reading automatically involves inner speech. They concluded that the blocking or facilitation of inner speech respectively decreased or increased the awareness of mind-wandering. One can however argue that both tasks had also a direct impact on mind-wandering itself, and not only its awareness, as repeated articulation may also reduce monitoring of mind-wandering while the presentation of written material may provide cues generating thoughts and associated mind-wandering. However, more research is needed for clarifying the possible influence of inner speech on conscious content. Although inner speech is commonly seen as a key feature of one's subjective experience (Fernyhough and Borghi, 2023), the occurrence of inner speech varies strongly within and between individuals (Heavey and Hurlburt, 2008; Nedergaard and Lupyan, 2023). The term 'anendophasia' was recently proposed to refer to the lack of the experience of inner speech, which would have behavioral consequences on performance in some language-related cognitive tasks (i.e., verbal working memory task and rhyme judgments) (Nedergaard and Lupyan, 2023). Future studies should determine whether the absence of subjective experience of language could more particularly affect consciousness content referring to other modalities in people with anendophasia.

Overall, language processing seems to influence the content of consciousness, as most specifically evidenced by the influence of lexico-semantic activation on visual awareness. In the next section, we specifically address higher-order conscious thought in its interaction with language and the impact of language impairment.

5. Higher-order conscious thought and language

The scientific literature includes studies reporting on the existence of relationships between language abilities and higher-order cognitive skills that are commonly associated with the phenomenon of consciousness, including self-awareness or metacognition. Evidence from aphasia particularly illuminates the association between language and higher-order conscious thought. Although individuals with aphasia generally retain global consciousness (Fedorenko and Varley, 2016), specific conscious processes, particularly self-awareness and metacognition, can be altered. Anosognosia, affecting approximately 20-25% of patients with left hemisphere damage, is perhaps the most significant example (Skipper, 2022).

This cognitive impairment can be subdivided into lack of intellectual awareness (general knowledge that a specific cognitive function is impaired in oneself), lack of emergent awareness (knowledge that an error is being made) and lack of anticipatory awareness (foreknowledge that a mistake might be made) (van der Stelt et al., 2021). Regarding intellectual awareness, van der Stelt and colleagues (2021) examined subjective experiences of anomia (via patient interview and a continuous rating scale) and confronted it with formal language testing. Post-stroke aphasic patients who gave unreliable or inaccurate estimates and ratings of their naming ability showed greater impairment on semantic tasks such as single word comprehension or category judgment, demonstrating both impaired internal awareness and semantic skills. In another study, measures of metacognition (i.e., emergent awareness or online self-correction of naming errors during a language task) were associated with comprehension but not production deficits (Dean et al., 2016). These results suggest a relationship between acquired language disorders and impaired higher-order conscious thought. At the same time, these aspects related to

consciousness may influence language performance as evidenced by studies showing that metacognitive training can enhance functional language recovery (Bampa et al., 2021; Wadams et al., 2022).

Furthermore, some studies have focused on inner speech in aphasia (Fama et al., 2019; Langland-Hassan et al., 2017; Tichborne et al., 2023). Analyzing autobiographical accounts written by people with aphasia, it was found that those who described impaired inner speech identified this aspect as 'the key feature of their aphasia, affecting cognition and sense of self, as well as language production, engagement in rehabilitation and conceptualization of recovery' (Tichborne et al., 2023). Moreover, Langland-Hassan and colleagues (2017) observed that inner speech deficits (inferred by means of a silent rhyming task) were associated with impaired metacognitive assessments of performance in categorization tasks in patients with aphasia (Langland-Hassan et al., 2017). During a silent naming task, other patients were asked to report whether they could say the name of items inside their heads. This self-reported inner speech was related to their performance on tasks requiring phonological retrieval of the same items (Fama et al., 2019). Patients with unreliable reporting of inner speech were also more severely impaired regarding both language processing and internal awareness (i.e., error recognition).

Going one step further, studies using self-report questionnaires in healthy adults have finally suggested that self-awareness measures (including self-focused attention and self-acceptance) mediate the relationship between inner speech and self-regulation (Morin, 2018; Racy and Morin, 2024). Overall, these findings align with Skipper's hypothesis that language, and particularly inner speech, may generate and sustain self-awareness (Skipper, 2022).

6. Integrative and critical discussion

In this final section, we aim to summarize and critically evaluate the reviewed findings, discuss their theoretical implications, and highlight the methodological challenges involved in examining the interaction between language and consciousness.

6.1. Quantitative aspects of consciousness

The studies we reviewed on language processing during sleep and anesthesia suggest that low-level acoustic and lexico-semantic processing is possible without consciousness. On the other hand, higher-level integration of semantic information appears to be absent or to elicit limited brain activation when participants are sedated or asleep (Fogel et al., 2022; Krom et al., 2020; Naci et al., 2018). Similarly, brain responses in UWS patients primarily reflect low-level auditory processing, whereas, in higher states of consciousness (i.e., from MCS- and MCS+ to emergence), brain responses increasingly indicate more complex semantic integration (Gui et al., 2020; Naci et al., 2018).

Most of these findings, however, rely on methodologies that may not accurately distinguish between the different low-level and high-level aspects that define language processing. A number of recent EEG studies on language processing and consciousness involve neural tracking paradigms of speech stimuli (e.g., Gui et al., 2020; Makov et al., 2017; Sokoliuk et al., 2021), which, however, do not allow to clearly separate sentence-level and acoustic aspects given that these aspects are correlated in natural speech contexts (Gillis et al., 2022). As a consequence, neural tracking of semantic processing may actually be confounded with acoustic processing (Kösem et al., 2023). In addition, fMRI studies tend to show language-related engagement of distinct cortical areas as a function of consciousness state, but we can only speculate about the specific aspects of language that are involved here, via reverse

406 inference based on previous studies on the neurobiology of language. Likewise, the
407 frontoparietal activity foci observed in these studies in response to language stimuli may reflect
408 attentional or executive control processes elicited by the narratives rather than high-level
409 semantic integration. Future studies need to examine in a more direct and accurate manner
410 which aspects of language processing remain functional when consciousness is reduced in
411 healthy controls, by contrasting brain responses to carefully selected language stimuli.

412 Studies on disorders of consciousness highlight important clinical implications. Although they
413 tend to confirm that recovery from language deficits and consciousness impairment follows
414 parallel trajectories (Aubinet et al., 2022), a special case is the situation of neural tracking of
415 higher-level aspects of language processing in patients behaviorally diagnosed as unconscious
416 (i.e., high-level covert cortical processing). For example, an increased N400 peak amplitude - in
417 response to incongruous sentence endings, indicating preserved semantic anomaly detection -
418 has been observed in some unresponsive patients, although with delayed responses (Balconi et
419 al., 2013; Balconi and Arangio, 2015). Similar results have been obtained using an fMRI-based
420 paradigm, in which patients with a behavioral diagnosis of UWS exhibited differential brain
421 responses to factually correct versus incorrect sentences (Kotchoubey et al., 2013). These
422 cases may indicate that, unlike our conclusions so far, the presence of high-level language
423 integration is possible in the absence of consciousness. Yet, we cannot exclude the possibility
424 that these specific patients, while diagnosed as being in a state associated with
425 unconsciousness, were actually conscious. Indeed, there is a well-documented, elevated risk
426 of behavioral misdiagnosis (Schnakers et al., 2009; van Erp et al., 2015; Wang et al., 2020;
427 Wannez et al., 2017) and a high likelihood of covert consciousness (Aubinet et al., 2025a;
428 Bodien et al., 2024; Claassen et al., 2024) in this population.

6.2. Qualitative aspects of consciousness

Cognitive studies examining conscious and unconscious content in awake participants seem to converge with research contrasting consciousness states based on sleep and anesthesia. At the word level, elementary semantic associations of unconsciously perceived stimuli are possible, but conscious perception appears to be required for higher-level semantic integration including the processing of metaphoric associations (Chien et al., 2023). We also observed low evidence for the possibility of semantic integration in phrase and sentence contexts when verbal stimuli do not reach visual awareness (Mongelli et al., 2019; Mudrik and Deouell, 2022; Nakamura et al., 2018; Rabagliati et al., 2018). Although these studies use visual paradigms, similar results are expected across different sensory modalities. A recent study suggests that auditory and visual perception rely on similar cortical and subcortical networks, indicating shared mechanisms of conscious perception (Christison-Lagay et al., 2025).

Nevertheless, we need to remain cautious about these results as many studies in this field are associated with low statistical power and with uncertainty regarding the optimal prime duration for stimuli to be perceived as conscious or not (Rabagliati et al., 2018; Stein et al., 2024). Moreover, participants in these paradigms are generally asked to perform a specific task (e.g., categorical judgment) involving motor or verbal explicit responses and cognitive control. The ecological validity of such responses was recently questioned (e.g., motor responses require learning task-specific response associations), and alternative measures such as spontaneous eye movement responses should be considered in future research (Mudrik et al., 2024).

6.3. Causality and theoretical implications

Studying the interaction between language and consciousness is particularly challenging due to the lack of a consensus on the definition of consciousness. Consciousness is a multifaceted

concept that encompasses subjective experiences only accessible from a first-person perspective (Seth and Bayne, 2022; Walter, 2021). We here chose to consider language aspects in interaction with both quantitative and qualitative aspects of consciousness because most theorists agree on such a two-dimensional conception of consciousness (Bayne et al., 2016; Overgaard and Overgaard, 2010; Seth and Bayne, 2022). When considering causal relationships, consciousness multidimensionality is, however, inadequately captured by simple notions of necessity and sufficiency, with multiple factors acting as partial contributors rather than direct causes (Skipper, 2022).

As previously stated, leading theories of consciousness, such as the *Global Neuronal Workspace Theory* (Dehaene et al., 2011; Mashour et al., 2020) or the *Integrated Information Theory* (Albantakis et al., 2023; Tononi et al., 2016), primarily mention language as a tool for reporting conscious thoughts (Budson et al., 2022; Graziano et al., 2020; Gross, 2018; Hermann et al., 2022; Mashour et al., 2020; Naccache, 2018; Seth and Bayne, 2022). We here argue that language and consciousness may be interdependent, enriching each other to support communication (Fedotov and Baidyuk, 2023). On the one hand, we emphasize a certain parallelism between their recovery trajectories and the idea that conscious processing is required for higher levels of language integration (or the processes supporting such integration). Inversely, we show that (at least) some language aspects can influence our conscious experience, as lexico-semantic processing of information can impact the level and duration of awareness of the same information in visual perceptual tasks (Fugate et al., 2020; Weller et al., 2019). Moreover, the restoration of language and related processes may precede and serve as a predictor of the reemergence of a consciousness state after coma (e.g., Formisano et al., 2019; Sokoliuk et al., 2021). These findings may consequently speak for a potential contribution of language processing to both qualitative and quantitative aspects of consciousness.

Nevertheless, two other explanations must be ruled out to confirm such a bilateral interdependence between language and consciousness.

The first one is that language may play a role in shaping higher-order, reflective conscious cognition, exclusively. Indeed, aphasia and deficits in inner speech are associated with impaired self-awareness and metacognition, while interventions targeting metacognition can enhance language recovery (Skipper, 2022; Fama et al., 2019; Bampa et al., 2021). Studies in healthy adults also indicate that self-awareness mediates the link between inner speech and self-regulation (Morin, 2018; Racy and Morin, 2024). Together, these findings support the existence of a bidirectional relationship between linguistic and such higher-order cognitive capacities, which aligns with the HOLISTIC model (Skipper, 2022). This is also consistent with the view that most animals could possess primary consciousness (i.e., in a first-order sense), but only a few would be capable of higher-order conscious thought and complex reasoning, for which language is necessary (Miguens, 2022). Future perspectives therefore include robust empirical studies focusing on the interaction between the aspects of language processing and consciousness components requiring or not requiring high-level cognition.

The second alternative hypothesis is that conscious processing may not be required for (or be influenced by) high-level linguistic processing per se, but rather for the integrative mechanisms that underlie such aspects of language. Language processing may be viewed as part of a broader perceptual and cognitive process of 'integration' (i.e., the generation of a non-perceptual, abstract representation through the association of distinct signals into a unified one) (Mudrik et al., 2014). According to the 'windows of integration hypothesis' (Hirschhorn et al., 2021), the necessity of conscious processing in integrating two or more representations into a novel one depends on the size of the integration window, which can be defined not only semantically, but

499 also temporally or spatially. The proposed association between language and consciousness
500 may thus be accounted for by more general integrative mechanisms that are not specific to
501 language. In other words, higher semantic and morphosyntactic levels of language may be
502 related to higher state of consciousness and the conscious processing of verbal content,
503 primarily due to the involvement of larger windows of integration rather than their specific
504 linguistic nature. In this case, the presumed interdependence between high-level language
505 processing and consciousness would be mediated by integrative skills. Nevertheless, phonetic
506 processing of language stimuli requires substantial contextual integration of the multiple, noisy,
507 and complex sensory features that allow our brain to distinguish, for example, voiced from
508 unvoiced consonants or to differentiate speech from non-speech sounds. As shown in this
509 review, individuals in states of altered consciousness or in unconscious conditions exhibit
510 differentiated brain responses to these lower-level linguistic features, despite the high
511 integrative demands involved. Therefore, our conclusions regarding preserved versus non-
512 preserved language processes as a function of consciousness state cannot be reduced to
513 integrated information processing alone. Further research should aim to isolate the language-
514 specific contribution to integration in comparison to other forms of information integration and
515 take into account this complexity for moving towards more integrative and comprehensive
516 theoretical frameworks of consciousness.

517 ***6.4. Methodological circularity in consciousness assessment***

518 Assessing our subjective experience importantly depends on our ability to explicitly report it, a
519 process that typically involves language. This remains a key issue in many of the studies
520 reviewed here.

In sleep and anesthesia studies, recovery from unconsciousness is defined by the earliest instance at which subjects behaviorally respond to verbal commands (e.g., Mashour et al., 2021). The same method is used to probe for both overt and covert consciousness states in post-comatose patients with severe acquired brain injury (Bayne et al., 2016). When opening their eyes, these patients are typically asked to squeeze the hand, open the mouth or move a limb, and considered as being conscious as soon as they can adequately and reproducibly respond to verbal commands. Regarding behavioral cognitive studies, many of the tasks used to assess connectedness and internal awareness (as in Table 1) also involve language-based self-report of one's own conscious perception of stimuli or experiences (Block, 2019; Naccache, 2018). Language processing is consequently intrinsically implicated in tasks assessing consciousness, which induces a problem of circularity when trying to interpret the results in terms of either consciousness or language processing abilities (Aubinet et al., 2025b).

Some authors have proposed new strategies to mitigate these biases. For example, recent neuroimaging studies incorporating awareness tasks have compared brain activity in both 'report' and 'no-report' conditions (Block, 2019). Using this paradigm, occipitotemporal and parietal cortex activity remained stable across both conditions in visual awareness tasks, whereas significant frontal cortex activity was observed only when participants reported their visual conscious experiences (Hatamimajoumerd et al., 2022). Such tasks may offer a better direction for identifying the neural mechanisms underlying perceptual awareness. In addition, various methods not relying on language processing have emerged, notably in the field of disorders of consciousness, including stimulus-free resting state paradigms or tasks based on tactile, olfactory or non-linguistic auditory stimuli (Arzi et al., 2020; Bekinschtein et al., 2009; Kazazian et al., 2025). Also, complexity-related measures of neural processing (i.e., perturbational complexity index) are considered as reliable markers of consciousness state

across many different conditions, such as sleep, anesthesia and disorders of consciousness (Casali et al., 2013; Casarotto et al., 2016; Sarasso et al., 2021), without needing any behavioral response by the patient. Building on these approaches, recent work has underscored the urgent need to develop validated consciousness tests applicable to a broad range of systems and populations, including patients with severe brain injury (Bayne et al., 2024). To this end, the authors propose a bootstrapping approach, beginning validation with neurotypical individuals in globally unresponsive states and gradually extending to more challenging groups.

6.5. Conclusion

Even if language is undoubtedly not the sole determinant of consciousness, this review highlights the existence of bidirectional interactions while also identifying several theoretical and methodological challenges in studying and interpreting them. Future research should more precisely define the specific aspects of language and dimensions of consciousness that interact and, crucially, investigate the potential causality of these interactions.

Glossary

Inner speech: subjective experience of language in the absence of articulation, also called covert language, silent speech or self-talk

Primary consciousness: aware processing of the environment, related to basic perceptual, sensory, emotional content, also observed in non-human species

Higher-order consciousness: form of extended or reflective consciousness that encompasses self-awareness and meta-awareness, allowing the individual to reflect on their own mental states

Consciousness state: global state of arousal referring to quantitative aspects of consciousness

Consciousness content: specific information or representations present in consciousness at a given moment and referring to qualitative aspects of consciousness

Self-awareness: conscious experience of self-related content including having mental representations of the self or becoming the object of one's own attention

Metacognition: reflective capacity that allows individuals to assess the accuracy or reliability of their own cognitive states

Connectedness: connection to the external world allowing the experience of external stimuli and responsiveness to these stimuli

Internal awareness: all thoughts not generated by external stimuli

Cognitive-motor dissociation: detection of response to commands or explicit language processing in absence of language-related behavioral signs of consciousness

Covert cortical processing: detection of association cortex responses to language or implicit language processing in absence of language-related behavioral signs of consciousness

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Competing interest

The authors declare no competing interest.

References

Albantakis, L., Barbosa, L., Findlay, G., Grasso, M., Haun, A.M., Marshall, W., Mayner, W.G.P., Zaeemzadeh, A., Boly, M., Juel, B.E., Sasai, S., Fujii, K., David, I., Hendren, J., Lang, J.P., Tononi, G., 2023. Integrated information theory (IIT) 4.0: Formulating the properties of phenomenal existence in physical terms. PLOS Computational Biology 19, e1011465. https://doi.org/10.1371/journal.pcbi.1011465

Alderson-Day, B., Fernyhough, C., 2015. Inner speech: Development, cognitive functions, phenomenology, and neurobiology. Psychological Bulletin 141, 931–965.

Andrillon, T., Poulsen, A.T., Hansen, L.K., Léger, D., Kouider, S., 2016. Neural Markers of Responsiveness to the Environment in Human Sleep. J Neurosci 36, 6583–6596. https://doi.org/10.1523/JNEUROSCI.0902-16.2016

Arzi, A., Rozenkrantz, L., Gorodisky, L., Rozenkrantz, D., Holtzman, Y., Ravia, A., Bekinschtein, T.A., Galperin, T., Krimchansky, B.-Z., Cohen, G., Oksamitni, A., Aidinoff, E., Sacher, Y., Sobel, N., 2020. Olfactory sniffing signals consciousness in unresponsive patients with brain injuries. Nature 581, 428–433. https://doi.org/10.1038/s41586-020-2245-5

Aubinet, C., Chatelle, C., Gosseries, O., Carrière, M., Laureys, S., Majerus, S., 2022. Residual implicit and explicit language abilities in patients with disorders of consciousness: A systematic review. Neuroscience & Biobehavioral Reviews 132, 391–409.

Aubinet, C., Claassen, J., Edlow, B.L., Fischer, D., Gosseries, O., Koch, C., Kondziella, D., Massimini, M., Young, M.J., 2025a. Covert consciousness: what's in a name? Brain awaf349. https://doi.org/10.1093/brain/awaf349

Aubinet, C., Gillet, A., Regnier, A., 2025b. Language, Communication and Consciousness Disorders in Severe Brain Injury. Psychologica Belgica 65, 169–188.

Avneon, M., Lamy, D., 2019. Do semantic priming and retrieval of stimulus-response associations depend on conscious perception? Consciousness and Cognition 69, 36–51. https://doi.org/10.1016/j.concog.2019.01.010

Balconi, M., Arangio, R., 2015. The Relationship Between Coma Near Coma, Disability Ratings, and Event-Related Potentials in Patients with Disorders of Consciousness: A Semantic Association Task. Applied Psychophysiology Biofeedback 40, 327–337.

Balconi, M., Arangio, R., Guarnerio, C., 2013. Disorders of consciousness and N400 ERP measures in response to a semantic task. Journal of Neuropsychiatry and Clinical Neurosciences 25, 237–243.

Bampa, G., Moraitou, D., Metallidou, P., 2021. Metacognition in Cognitive Rehabilitation in Adults: A Systematic Review, in: Moraitou, D., Metallidou, P. (Eds.), Trends and Prospects in Metacognition Research across the Life Span: A Tribute to Anastasia Efklides. Springer International Publishing, Cham, pp. 273–295. https://doi.org/10.1007/978-3-030-51673-4_13

Bastian, M., Lerique, S., Adam, V., Franklin, M.S., Schooler, J.W., Sackur, J., 2017. Language facilitates introspection: Verbal mind-wandering has privileged access to consciousness. Consciousness and Cognition 49, 86–97. https://doi.org/10.1016/j.concog.2017.01.002

Bayne, T., Hohwy, J., Owen, A.M., 2016. Are There Levels of Consciousness? Trends in Cognitive Sciences 20, 405–413. https://doi.org/10.1016/j.tics.2016.03.009
Bayne, T., Seth, A.K., Massimini, M., Shepherd, J., Cleeremans, A., Fleming, S.M., Malach, R., Mattingley, J.B., Menon, D.K., Owen, A.M., Peters, M.A.K., Razi, A., Mudrik, L., 2024. Tests for consciousness in humans and beyond. Trends in Cognitive Sciences 28, 454–466. https://doi.org/10.1016/j.tics.2024.01.010
Bekinschtein, T.A., Dehaene, S., Rohaut, B., Tadel, F., Cohen, L., Naccache, L., 2009. Neural signature of the conscious processing of auditory regularities. Proc Natl Acad Sci U S A 106, 1672–1677. https://doi.org/10.1073/pnas.0809667106
Berkovitch, L., Dehaene, S., 2019. Subliminal syntactic priming. Cogn Psychol 109, 26–46.
Biderman, D., Shir, Y., Mudrik, L., 2020. B or 13? Unconscious Top-Down Contextual Effects at the Categorical but Not the Lexical Level. Psychological Science 31, 663–677.
Block, N., 2019. What Is Wrong with the No-Report Paradigm and How to Fix It. Trends in Cognitive Sciences 23, 1003–1013. https://doi.org/10.1016/j.tics.2019.10.001
Block, N., 1995. On a confusion about a function of consciousness. BEHAVIORAL AND BRAIN SCIENCES.
Bodien, Y.G., Allanson, J., Cardone, P., Bonhomme, A., Carmona, J., Chatelle, C., Chennu, S., Conte, M., Dehaene, S., Finoia, P., Heinonen, G., Hersh, J.E., Kamau, E., Lawrence, P.K., Lupson, V.C., Meydan, A., Rohaut, B., Sanders, W.R., Sitt, J.D., Soddu, A., Valente, M., Velazquez, A., Voss, H.U., Vrosgou, A., Claassen, J., Edlow, B.L., Fins, J.J., Gosseries, O., Laureys, S., Menon, D., Naccache, L., Owen, A.M., Pickard, J., Stamatakis, E.A., Thibaut, A., Victor, J.D., Giacino, J.T., Bagiella, E., Schiff, N.D., 2024. Cognitive Motor Dissociation in Disorders of Consciousness. N Engl J Med 391, 598–608.
Bonhomme, V., Staquet, C., Montupil, J., Defresne, A., Kirsch, M., Martial, C., Vanhaudenhuyse, A., Chatelle, C., Larroque, S.K., Raimondo, F., Demertzi, A., Bodart, O., Laureys, S., Gosseries, O., 2019. General Anesthesia: A Probe to Explore Consciousness. Front. Syst. Neurosci. 13. https://doi.org/10.3389/fnsys.2019.00036
Brown, R., Lau, H., LeDoux, J.E., 2019. Understanding the Higher-Order Approach to Consciousness. Trends in Cognitive Sciences 23, 754–768. https://doi.org/10.1016/j.tics.2019.06.009
Bruno, M.A., Vanhaudenhuyse, A., Thibaut, A., Moonen, G., Laureys, S., 2011. From unresponsive wakefulness to minimally conscious PLUS and functional locked-in syndromes: Recent advances in our understanding of disorders of consciousness. Journal of Neurology 258, 1373–1384.
Budson, A.E., Richman, K.A., Kensinger, E.A., 2022. Consciousness as a Memory System. Cognitive and Behavioral Neurology 35, 263. https://doi.org/10.1097/WNN.0000000000000319
Casali, A.G., Gosseries, O., Rosanova, M., Boly, M., Sarasso, S., Casali, K.R., Casarotto, S., Bruno, M.-A., Laureys, S., Tononi, G., Massimini, M., 2013. A theoretically based index of consciousness independent of sensory processing and behavior. Sci Transl Med 5, 198ra105. https://doi.org/10.1126/scitranslmed.3006294
Casarotto, S., Comanducci, A., Rosanova, M., Sarasso, S., Fecchio, M., Napolitani, M., Pigorini, A., G Casali, A., Trimarchi, P.D., Boly, M., Gosseries, O., Bodart, O., Curto, F., Landi, C., Mariotti, M., Devalle, G., Laureys, S., Tononi, G., Massimini, M., 2016. Stratification of unresponsive patients by an independently validated index of brain complexity. Ann Neurol 80, 718–729. https://doi.org/10.1002/ana.24779
Chien, S.-E., Chang, W.-C., Chen, Y.-C., Huang, S.-L., Yeh, S.-L., 2023. The limits of unconscious semantic priming. Curr Psychol 42, 26824–26835.
Christison-Lagay, K.L., Khalaf, A., Freedman, N.C., Micek, C., Kronemer, S.I., Gusso, M.M., Kim, L., Forman, S., Ding, J., Aksen, M., Abdel-Aty, A., Kwon, H., Markowitz, N., Yeagle, E., Espinal, E., Herrero, J., Bickel, S., Young, J., Mehta, A., Wu, K., Gerrard, J., Damisah, E.,

Spencer, D., Blumenfeld, H., 2025. The neural activity of auditory conscious perception. NeuroImage 308, 121041. https://doi.org/10.1016/j.neuroimage.2025.121041
Claassen, J., Doyle, K., Matory, A., Couch, C., Burger, K.M., Velazquez, A., Okonkwo, J.U., King, J.R., Park, S., Agarwal, S., Roh, D., Megjhani, M., Eliseyev, A., Sander Connolly, E., Rohaut, B., 2019. Detection of brain activation in unresponsive patients with acute brain injury. New England Journal of Medicine 380, 2497–2505.
Claassen, J., Kondziella, D., Alkhachroum, A., Diringer, M., Edlow, B.L., Fins, J.J., Gosseries, O., Hannawi, Y., Rohaut, B., Schnakers, C., Stevens, R.D., Thibaut, A., Monti, M., Curing Coma Campaign, and Its Contributing Collaborators, 2024. Cognitive Motor Dissociation: Gap Analysis and Future Directions. Neurocrit Care 40, 81–98. https://doi.org/10.1007/s12028-023-01769-3
Dean, M.P., Della Sala, S., Beschin, N., Cocchini, G., 2016. Anosognosia and self-correction of naming errors in aphasia. Aphasiology 31, 725–740.
Dehaene, S., Changeux, J.-P., Naccache, L., 2011. The Global Neuronal Workspace Model of Conscious Access: From Neuronal Architectures to Clinical Applications, in: Dehaene, S., Christen, Y. (Eds.), Characterizing Consciousness: From Cognition to the Clinic?, Research and Perspectives in Neurosciences. Springer, Berlin, Heidelberg, pp. 55–84. https://doi.org/10.1007/978-3-642-18015-6_4
Dennett, D.C., 2017. Brainstorms, Fortieth Anniversary Edition: Philosophical Essays on Mind and Psychology. MIT Press.
Edelman, G.M., Gally, J.A., Baars, B.J., 2011. Biology of Consciousness. Front. Psychology 2. https://doi.org/10.3389/fpsyg.2011.00004
Edlow, B.L., Claassen, J., Schiff, N.D., Greer, D.M., 2021. Recovery from disorders of consciousness: mechanisms, prognosis and emerging therapies. Nat Rev Neurol 17, 135–156. https://doi.org/10.1038/s41582-020-00428-x
Egbebike, J., Shen, Q., Doyle, K., Der-Nigoghossian, C.A., Panicker, L., Gonzales, I.J., Grobois, L., Carmona, J.C., Vrosgou, A., Kaur, A., Boehme, A., Velazquez, A., Rohaut, B., Roh, D., Agarwal, S., Park, S., Connolly, E.S., Claassen, J., 2022. Cognitive-motor dissociation and time to functional recovery in patients with acute brain injury in the USA: a prospective observational cohort study. The Lancet Neurology 21, 704–713. https://doi.org/10.1016/S1474-4422(22)00212-5
Eiserbeck, A., Enge, A., Rabovsky, M., Abdel Rahman, R., 2022. Electrophysiological Chronometry of Graded Consciousness during the Attentional Blink. Cerebral Cortex 32, 1244–1259. https://doi.org/10.1093/cercor/bhab289
Eklund, R., Gerdfeldter, B., Wiens, S., 2021. The early but not the late neural correlate of auditory awareness reflects lateralized experiences. Neuropsychologia 158, 107910. https://doi.org/10.1016/j.neuropsychologia.2021.107910
Eklund, R., Gerdfeldter, B., Wiens, S., 2019. Effects of a Manual Response Requirement on Early and Late Correlates of Auditory Awareness. Frontiers in Psychology 10.
Fama, M.E., Snider, S.F., Henderson, M.P., Hayward, W., Friedman, R.B., Turkeltaub, P.E., 2019. The Subjective Experience of Inner Speech in Aphasia Is a Meaningful Reflection of Lexical Retrieval. J Speech Lang Hear Res 62, 106–122. https://doi.org/10.1044/2018_JSLHR-L-18-0222
Fedorenko, E., Varley, R., 2016. Language and thought are not the same thing: evidence from neuroimaging and neurological patients. Annals of the New York Academy of Sciences 1369, 132–153. https://doi.org/10.1111/nyas.13046
Fedotov, S.A., Baidyuk, E.V., 2023. Communication as the Origin of Consciousness. Integr. psych. behav. 57, 20–42.
Fernyhough, C., Borghi, A.M., 2023. Inner speech as language process and cognitive tool. Trends in Cognitive Sciences S1364661323002103. https://doi.org/10.1016/j.tics.2023.08.014

Fogel, S., Ray, L., Fang, Z., Silverbrook, M., Naci, L., Owen, A.M., 2022. While you were sleeping: Evidence for high-level executive processing of an auditory narrative during sleep. Consciousness and Cognition 100, 103306.
Formisano, R., Toppi, J., Risetti, M., Aloisi, M., Contrada, M., Ciurli, P.M., Falletta Caravasso, C., Luccichenti, G., Astolfi, L., Cincotti, F., Mattia, D., 2019. Language-Related Brain Potentials in Patients With Disorders of Consciousness: A Follow-up Study to Detect "Covert" Language Disorders. Neurorehabilitation and Neural Repair 33, 513–522.
Frankland, S.M., Greene, J.D., 2020. Concepts and Compositionality: In Search of the Brain's Language of Thought. Annual Review of Psychology 71, 273–303. https://doi.org/10.1146/annurev-psych-122216-011829
Fugate, J.M.B., MacDonald, C., O'Hare, A.J., 2020. Emotion Words' Effect on Visual Awareness and Attention of Emotional Faces. Front. Psychol. 10, 2896. https://doi.org/10.3389/fpsyg.2019.02896
Giacino, J.T., Ashwal, S., Childs, N., Cranford, R., Jennett, B., Katz, D.I., 2002. The minimally conscious state. Neurology 58, 349–353.
Giacino, J.T., Kalmar, K., Whyte, J., 2004. The JFK Coma Recovery Scale-Revised: Measurement characteristics and diagnostic utility. Archives of Physical Medicine and Rehabilitation 85, 2020–2029.
Giesbrecht, B., Sy, J.L., Elliott, J.C., 2007. Electrophysiological evidence for both perceptual and postperceptual selection during the attentional blink. J Cogn Neurosci 19, 2005–2018. https://doi.org/10.1162/jocn.2007.19.12.2005
Gillis, M., Van Canneyt, J., Francart, T., Vanthornhout, J., 2022. Neural tracking as a diagnostic tool to assess the auditory pathway. Hearing Research 426, 108607.
Graziano, M.S.A., Guterstam, A., Bio, B.J., Wilterson, A.I., 2020. Toward a standard model of consciousness: Reconciling the attention schema, global workspace, higher-order thought, and illusionist theories. Cognitive Neuropsychology 37, 155–172. https://doi.org/10.1080/02643294.2019.1670630
Gross, S., 2018. Perceptual consciousness and cognitive access from the perspective of capacity-unlimited working memory. Phil. Trans. R. Soc. B 373, 20170343. https://doi.org/10.1098/rstb.2017.0343
Grund, M., Forschack, N., Nierhaus, T., Villringer, A., 2021. Neural correlates of conscious tactile perception: An analysis of BOLD activation patterns and graph metrics. NeuroImage 224, 117384. https://doi.org/10.1016/j.neuroimage.2020.117384
Gui, P., Jiang, Y., Zang, D., Qi, Z., Tan, J., Tanigawa, H., Jiang, J., Wen, Y., Xu, L., Zhao, J., Mao, Y., Poo, M., Ding, N., Dehaene, S., Wu, X., Wang, L., 2020. Assessing the depth of language processing in patients with disorders of consciousness. Nat Neurosci 23, 761–770.
Hatamimajoumerd, E., Ratan Murty, N.A., Pitts, M., Cohen, M.A., 2022. Decoding perceptual awareness across the brain with a no-report fMRI masking paradigm. Curr Biol 32, 4139-4149.e4. https://doi.org/10.1016/j.cub.2022.07.068
Heavey, C.L., Hurlburt, R.T., 2008. The phenomena of inner experience. Consciousness and Cognition 17, 798–810. https://doi.org/10.1016/j.concog.2007.12.006
Hermann, B., Sangaré, A., Munoz-Musat, E., Salah, A.B., Perez, P., Valente, M., Faugeras, F., Axelrod, V., Demeret, S., Marois, C., Pyatigorskaya, N., Habert, M.-O., Kas, A., Sitt, J.D., Rohaut, B., Naccache, L., 2022. Importance, limits and caveats of the use of "disorders of consciousness" to theorize consciousness. Neurosci Conscious 2021, niab048. https://doi.org/10.1093/nc/niab048
Hirschhorn, R., Kahane, O., Gur-Arie, I., Faivre, N., Mudrik, L., 2021. Windows of Integration Hypothesis Revisited. Front Hum Neurosci 14, 617187. https://doi.org/10.3389/fnhum.2020.617187
Huang, Z., Liu, X., Mashour, G.A., Hudetz, A.G., 2018. Timescales of Intrinsic BOLD Signal Dynamics and Functional Connectivity in Pharmacologic and Neuropathologic States of

Unconsciousness. J Neurosci 38, 2304–2317. https://doi.org/10.1523/JNEUROSCI.2545-17.2018
Kazazian, K., Monti, M.M., Owen, A.M., 2025. Functional neuroimaging in disorders of consciousness: towards clinical implementation. Brain awaf075. https://doi.org/10.1093/brain/awaf075
Klink, P., C., van Wezel, R.J.A., van Ee, R., 2013. The future of binocular rivalry research: Reaching through a window on consciousness., in: The Constitution of Visual Consciousness: Lessons from Binocular Rivalry. John Benjamins Publishing Company, pp. 305–332.
Kösem, A., Dai, B., McQueen, J.M., Hagoort, P., 2023. Neural tracking of speech envelope does not unequivocally reflect intelligibility. NeuroImage 272, 120040.
Kotchoubey, B., Yu, T., Mueller, F., Vogel, D., Veser, S., Lang, S., 2013. True or false? Activations of language-related areas in patients with disorders of consciousness. Current Pharmaceutical Design 999, 27–28.
Kovacs, T., 2021. A Survey of American Speech-Language Pathologists' Perspectives on Augmentative and Alternative Communication Assessment and Intervention Across Language Domains. American Journal of Speech-Language Pathology 30, 1038–1048.
Krom, A.J., Marmelshtein, A., Gelbard-Sagiv, H., Tankus, A., Hayat, H., Hayat, D., Matot, I., Strauss, I., Fahoum, F., Soehle, M., Boström, J., Mormann, F., Fried, I., Nir, Y., 2020. Anesthesia-induced loss of consciousness disrupts auditory responses beyond primary cortex. Proc Natl Acad Sci U S A 117, 11770–11780.
Langland-Hassan, P., Gauker, C., Richardson, M.J., Dietz, A., Faries, F.R., 2017. Metacognitive deficits in categorization tasks in a population with impaired inner speech. Acta Psychologica 181, 62–74. https://doi.org/10.1016/j.actpsy.2017.10.004
Lau, H., Rosenthal, D., 2011. Empirical support for higher-order theories of conscious awareness. Trends in Cognitive Sciences 15, 365–373. https://doi.org/10.1016/j.tics.2011.05.009
Laureys, S., 2005. The neural correlate of (un)awareness: Lessons from the vegetative state. Trends in Cognitive Sciences 9, 556–559.
Laureys, S., Celesia, G.G., Cohadon, F., Lavrijsen, J., León-Carrión, J., Sannita, W.G., Dolce, G., 2010. Unresponsive wakefulness syndrome: a new name for the vegetative state or apallic syndrome. BMC Medicine 8, 68.
Llorens, R., Ippoliti, C., Navarro, M.D., Colomer, C., Maza, A., Goizueta, S., Olaya, J., Moliner, B., Ferri, J., Noé, E., 2024. Minimally conscious state plus versus minus: Likelihood of emergence and long-term functional independence. Ann Clin Transl Neurol. https://doi.org/10.1002/acn3.51993
Luck, S.J., Vogel, E.K., Shapiro, K.L., 1996. Word meanings can be accessed but not reported during the attentional blink. Nature 383, 616–618.
Lupyan, G., Rahman, R.A., Boroditsky, L., Clark, A., 2020. Effects of Language on Visual Perception. Trends in Cognitive Sciences 24, 930–944. https://doi.org/10.1016/j.tics.2020.08.005
Lupyan, G., Ward, E.J., 2013. Language can boost otherwise unseen objects into visual awareness. Proceedings of the National Academy of Sciences 110, 14196–14201. https://doi.org/10.1073/pnas.1303312110
Makov, S., Sharon, O., Ding, N., Ben-Shachar, M., Nir, Y., Zion Golumbic, E., 2017. Sleep Disrupts High-Level Speech Parsing Despite Significant Basic Auditory Processing. J Neurosci 37, 7772–7781.
Martial, C., Cassol, H., Laureys, S., Gosseries, O., 2020. Near-Death Experience as a Probe to Explore (Disconnected) Consciousness. Trends in Cognitive Sciences 24, 173–183. https://doi.org/10.1016/j.tics.2019.12.010
Mashour, G.A., 2024. Anesthesia and the neurobiology of consciousness. Neuron 112, 1553–1567.

Mashour, G.A., Palanca, B.J., Basner, M., Li, D., Wang, W., Blain-Moraes, S., Lin, N., Maier, K., Muench, M., Tarnal, V., Vanini, G., Ochroch, E.A., Hogg, R., Schwartz, M., Maybrier, H., Hardie, R., Janke, E., Golmirzaie, G., Picton, P., McKinstry-Wu, A.R., Avidan, M.S., Kelz, M.B., 2021. Recovery of consciousness and cognition after general anesthesia in humans. Elife 10, e59525. https://doi.org/10.7554/eLife.59525

Mashour, G.A., Roelfsema, P., Changeux, J.-P., Dehaene, S., 2020. Conscious Processing and the Global Neuronal Workspace Hypothesis. Neuron 105, 776–798. https://doi.org/10.1016/j.neuron.2020.01.026

Mehling, W.E., Acree, M., Stewart, A., Silas, J., Jones, A., 2018. The Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2). PLOS ONE 13, e0208034. https://doi.org/10.1371/journal.pone.0208034

Micher, N., Lamy, D., 2023. The role of conscious perception in semantic processing: Testing the action trigger hypothesis. Consciousness and Cognition 107, 103438. https://doi.org/10.1016/j.concog.2022.103438

Miguens, S., 2022. Animal Brains and the Work of Words: Daniel Dennett on Natural Language and the Human Mind. Topoi 41, 599–607. https://doi.org/10.1007/s11245-021-09745-2

Miller, S.E., 2022. Vocabulary and Early Executive Function during Early Childhood: Revisiting Questions on the Nature of Thought and Language – Commentary on Bruce and Bell. Human Development 66, 188–191. https://doi.org/10.1159/000525361

Mongelli, V., Meijs, E.L., van Gaal, S., Hagoort, P., 2019. No language unification without neural feedback: How awareness affects sentence processing. NeuroImage 202, 116063.

Morin, A., 2018. The Self-Reflective Functions of Inner Speech. Oxford University Press. https://doi.org/10.1093/oso/9780198796640.003.0012

Morin, A., 2006. Levels of consciousness and self-awareness: A comparison and integration of various neurocognitive views. Conscious Cogn 15, 358–371. https://doi.org/10.1016/j.concog.2005.09.006

Mudrik, L., Deouell, L.Y., 2022. Neuroscientific Evidence for Processing Without Awareness. Annual Review of Neuroscience 45, 403–423. https://doi.org/10.1146/annurev-neuro-110920-033151

Mudrik, L., Faivre, N., Koch, C., 2014. Information integration without awareness. Trends in Cognitive Sciences 18, 488–496.

Mudrik, L., Hirschhorn, R., Korisky, U., 2024. Taking consciousness for real: Increasing the ecological validity of the study of conscious vs. unconscious processes. Neuron 112, 1642–1656.

Naccache, L., 2018. Why and how access consciousness can account for phenomenal consciousness. Phil. Trans. R. Soc. B 373, 20170357. https://doi.org/10.1098/rstb.2017.0357

Naci, L., Haugg, A., MacDonald, A., Anello, M., Houldin, E., Naqshbandi, S., Owen, A.M., 2018. Functional diversity of brain networks supports consciousness and verbal intelligence. Scientific Reports 8, 1–15.

Nakamura, K., Kawabata, H., 2018. Preferential access to awareness of attractive faces in a breaking continuous flash suppression paradigm. Consciousness and Cognition 65, 71–82.

Nakamura, K., Makuuchi, M., Oga, T., Mizuochi-Endo, T., Iwabuchi, T., Nakajima, Y., Dehaene, S., 2018. Neural capacity limits during unconscious semantic processing. Eur J Neurosci 47, 929–937.

Nedergaard, J.S.K., Lupyan, G., 2023. Not Everyone Has an Inner Voice: Behavioral Consequences of Anendophasia. Proceedings of the Annual Meeting of the Cognitive Science Society 45.

O'Neill, S.P., 2015. Sapir–Whorf Hypothesis, in: The International Encyclopedia of Language and Social Interaction. John Wiley & Sons, Ltd, pp. 1–10. https://doi.org/10.1002/9781118611463.wbielsi086

Overgaard, M., Overgaard, R., 2010. Neural Correlates of Contents and Levels of Consciousness. Front Psychol 1, 164.
Palma, P., Titone, D., 2021. Something old, something new: A review of the literature on sleep-related lexicalization of novel words in adults. Psychon Bull Rev 28, 96–121. https://doi.org/10.3758/s13423-020-01809-5
Pinto, Y., van Gaal, S., de Lange, F.P., Lamme, V.A.F., Seth, A.K., 2015. Expectations accelerate entry of visual stimuli into awareness. Journal of Vision 15, 13. https://doi.org/10.1167/15.8.13
Rabagliati, H., Robertson, A., Carmel, D., 2018. The importance of awareness for understanding language. Journal of Experimental Psychology: General 147, 190–208.
Racy, F., Morin, A., 2024. Relationships between Self-Talk, Inner Speech, Mind Wandering, Mindfulness, Self-Concept Clarity, and Self-Regulation in University Students. Behavioral Sciences 14, 55. https://doi.org/10.3390/bs14010055
Ruch, S., Henke, K., 2020. Learning During Sleep: A Dream Comes True? Trends in Cognitive Sciences 24, 170–172. https://doi.org/10.1016/j.tics.2019.12.007
Sapir, E., 1929. The Status of Linguistics as a Science. Language 5, 207–214. https://doi.org/10.2307/409588
Sarasso, S., Casali, A.G., Casarotto, S., Rosanova, M., Sinigaglia, C., Massimini, M., 2021. Consciousness and complexity: a consilience of evidence. Neuroscience of Consciousness 2021, niab023. https://doi.org/10.1093/nc/niab023
Scheier, M.F., Carver, C.S., 1985. The Self-Consciousness Scale: A revised version for use with general populations. Journal of Applied Social Psychology 15, 687–699. https://doi.org/10.1111/j.1559-1816.1985.tb02268.x
Schnakers, C., Vanhaudenhuyse, A., Giacino, J., Ventura, M., Boly, M., Majerus, S., Moonen, G., Laureys, S., 2009. Diagnostic accuracy of the vegetative and minimally conscious state: clinical consensus versus standardized neurobehavioral assessment. BMC neurology 9, 35.
Schröder, P., Nierhaus, T., Blankenburg, F., 2021. Dissociating Perceptual Awareness and Postperceptual Processing: The P300 Is Not a Reliable Marker of Somatosensory Target Detection. Journal of Neuroscience 41, 4686–4696.
Seth, A.K., Bayne, T., 2022. Theories of consciousness | Nature Reviews Neuroscience. Nature Reviews Neuroscience 23, 439–452.
Skipper, J.I., 2022. A voice without a mouth no more: The neurobiology of language and consciousness. Neuroscience & Biobehavioral Reviews 140, 104772.
Sklar, A.Y., Goldstein, A.Y., Abir, Y., Goldstein, A., Dotsch, R., Todorov, A., Hassin, R.R., 2021. Did you see it? Robust individual differences in the speed with which meaningful visual stimuli break suppression. Cognition 211, 104638. https://doi.org/10.1016/j.cognition.2021.104638
Sokoliuk, R., Degano, G., Banellis, L., Melloni, L., Hayton, T., Sturman, S., Veenith, T., Yakoub, K.M., Belli, A., Noppeney, U., Cruse, D., 2021. Covert Speech Comprehension Predicts Recovery From Acute Unresponsive States. Ann Neurol 89, 646–656. https://doi.org/10.1002/ana.25995
Stein, T., van Gaal, S., Fahrenfort, J.J., 2024. How (not) to demonstrate unconscious priming: Overcoming issues with post-hoc data selection, low power, and frequentist statistics. Conscious Cogn 119, 103669.
Steppacher, I., Fuchs, P., Kaps, M., Nussbeck, F.W., Kissler, J., 2020. A tree of life? Multivariate logistic outcome-prediction in disorders of consciousness A tree of life? Multivariate logistic outcome-prediction in disorders of consciousness. Brain Injury 34, 399–406.
Tagliazucchi, E., Behrens, M., Laufs, H., 2013. Sleep Neuroimaging and Models of Consciousness. Front Psychol 4, 256. https://doi.org/10.3389/fpsyg.2013.00256
Thibaut, A., Bodien, Y.G., Laureys, S., Giacino, J.T., 2019. Minimally conscious state “ plus ”: diagnostic criteria and relation to functional recovery. Journal of Neurology.

Tichborne, B., Liu, F., Bose, A., 2023. Subjective Experience of Word Production Difficulties in Aphasia: a Metaphor Analysis of Autobiographical Accounts. Aphasiology 0, 1–33. https://doi.org/10.1080/02687038.2023.2243672
Tononi, G., Boly, M., Cirelli, C., 2024. Consciousness and sleep. Neuron 112, 1568–1594. https://doi.org/10.1016/j.neuron.2024.04.011
Tononi, G., Boly, M., Massimini, M., Koch, C., 2016. Integrated information theory: from consciousness to its physical substrate. Nat Rev Neurosci 17, 450–461. https://doi.org/10.1038/nrn.2016.44
van der Stelt, C.M., Fama, M.E., Mccall, J.D., Snider, S.F., Turkeltaub, P.E., 2021. Intellectual awareness of naming abilities in people with chronic post-stroke aphasia. Neuropsychologia 160, 107961. https://doi.org/10.1016/j.neuropsychologia.2021.107961
van Erp, W.S., Lavrijsen, J.C.M., Vos, P.E., Bor, H., Laureys, S., Koopmans, R.T.C.M., 2015. The Vegetative State: Prevalence, Misdiagnosis, and Treatment Limitations. Journal of the American Medical Directors Association 16, 85.e9-85.e14.
van Gaal, S., Naccache, L., Meuwese, J.D.I., van Loon, A.M., Leighton, A.H., Cohen, L., Dehaene, S., 2014. Can the meaning of multiple words be integrated unconsciously? Philos Trans R Soc Lond B Biol Sci 369, 20130212. https://doi.org/10.1098/rstb.2013.0212
Wadams, A., Suting, L., Lindsey, A., Mozeiko, J., 2022. Metacognitive Treatment in Acquired Brain Injury and Its Applicability to Aphasia: A Systematic Review. Frontiers in Rehabilitation Sciences 3.
Walter, J., 2021. Consciousness as a multidimensional phenomenon: implications for the assessment of disorders of consciousness. Neuroscience of Consciousness 2021, niab047. https://doi.org/10.1093/nc/niab047
Wang, J., Hu, X., Hu, Z., Sun, Z., Laureys, S., Di, H., 2020. The misdiagnosis of prolonged disorders of consciousness by a clinical consensus compared with repeated coma-recovery scale-revised assessment. BMC Neurol 20, 343. https://doi.org/10.1186/s12883-020-01924-9
Wannez, S., Heine, L., Thonnard, M., Gosseries, O., Laureys, S., 2017. The repetition of behavioral assessments in diagnosis of disorders of consciousness. Annals of Neurology 81, 883–889.
Weller, P.D., Rabovsky, M., Abdel Rahman, R., 2019. Semantic Knowledge Enhances Conscious Awareness of Visual Objects. Journal of Cognitive Neuroscience 31, 1216–1226. https://doi.org/10.1162/jocn_a_01404
Whorf, B.L., 1956. Language, Thought, and Reality: Selected writings of Benjamin Lee Whorf, Massachusetts Institute of Technology. ed. Cambridge.
Wilke, M., Logothetis, N.K., Leopold, D.A., 2003. Generalized Flash Suppression of Salient Visual Targets. Neuron 39, 1043–1052. https://doi.org/10.1016/j.neuron.2003.08.003
Young, M.J., Fecchio, M., Bodien, Y.G., Edlow, B.L., 2024. Covert cortical processing: a diagnosis in search of a definition. Neurosci Conscious 2024, niad026. https://doi.org/10.1093/nc/niad026

Tables

Table 1. Examples of tasks used to assess the content of connectedness and internal awareness.

Connectedness				**Internal awareness**	
Visual perception	Auditory perception	Tactile perception	Language perception	Self-consciousness	Inner speech
- Detection of behavioral responses to visual stimuli (recognition, pursuit, and fixation) - Flash suppression, binocular rivalry, and attentional blink tasks	- Detection of behavioral responses to auditory stimuli - Auditory event-related potentials (ERPs) - Tone detection tasks	- Detection of behavioral responses to tactile or painful stimuli - Somato-sensory/ tactile detection tasks	- Detection of behavioral or covert responses to verbal commands - Language discrimination/ priming tasks - ERPs (N400)	- Responses to self-referential stimuli (e.g., own name, own face) - Default-mode network activation - Self-consciousness questionnaires (e.g., Scheier and Carver, 1985; Mehling et al., 2018)	- Observation of the development of private speech - Language network activation - Experience sampling, dual-task designs, silent rhyming or naming tasks

Figures

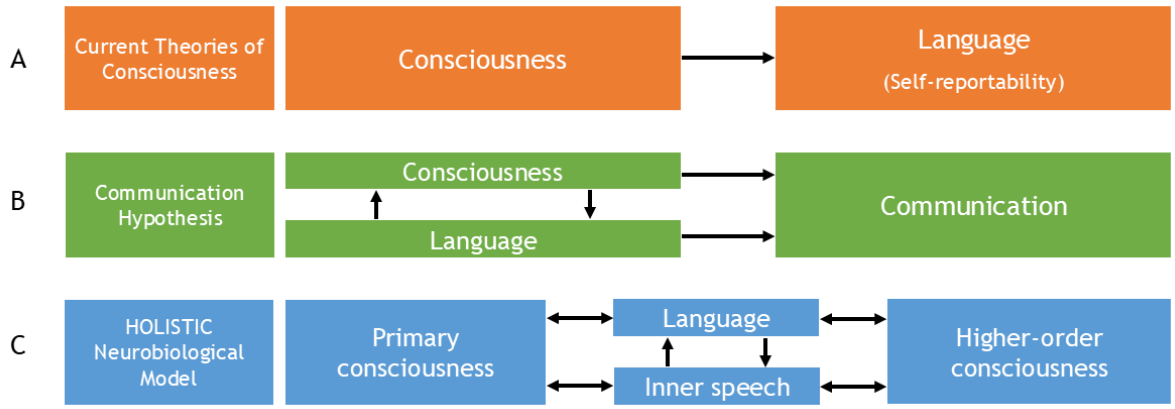

Figure 1. Functional interactions between language, consciousness and communication. *Whereas leading theories of consciousness (e.g., Graziano et al., 2020; Gross, 2018; Hermann et al., 2022; Mashour et al., 2020; Naccache, 2018) primarily view language as a means of reporting conscious experience, thus considering it a post-conscious process (A), recent theoretical perspectives suggest a closer association between human language and consciousness. Some propose that the communicative function of language serves as the foundation of consciousness (Fedotov and Baidyuk, 2023; Miguens, 2022) (B), while others argue that language and inner speech support the emergence of higher-order consciousness (i.e., self-awareness) in contrast to primary consciousness (Skipper, 2022) (C).*

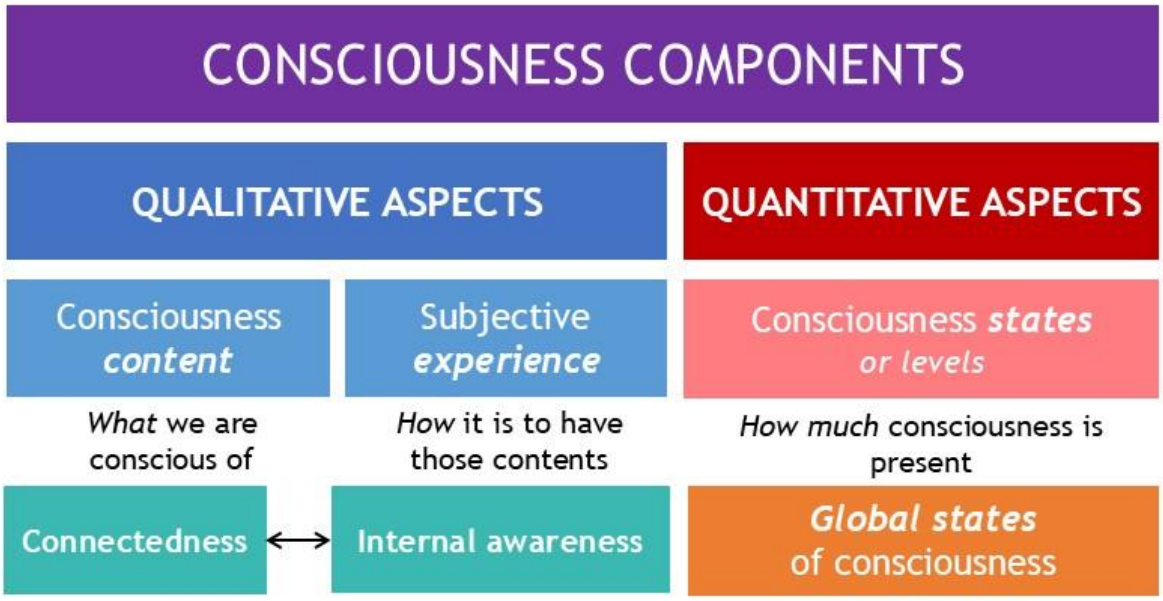

Figure 2. Consciousness components based on qualitative and quantitative aspects. *Consciousness is commonly described as a bidimensional phenomenon, encompassing both its content and states* (Laureys, 2005). *The content of consciousness is the specific information, or representations present in the mind at a given moment, distinct from subjective experience, which is characterized by what it feels like to have this content. The term 'content of consciousness' also encompasses other distinctions found in the literature, such as connectedness versus internal awareness content* (Martial et al., 2020). *In contrast, the states or levels of consciousness refer to global states of arousal, including sleep stages, drug-induced states or post-comatose disorders of consciousness.*

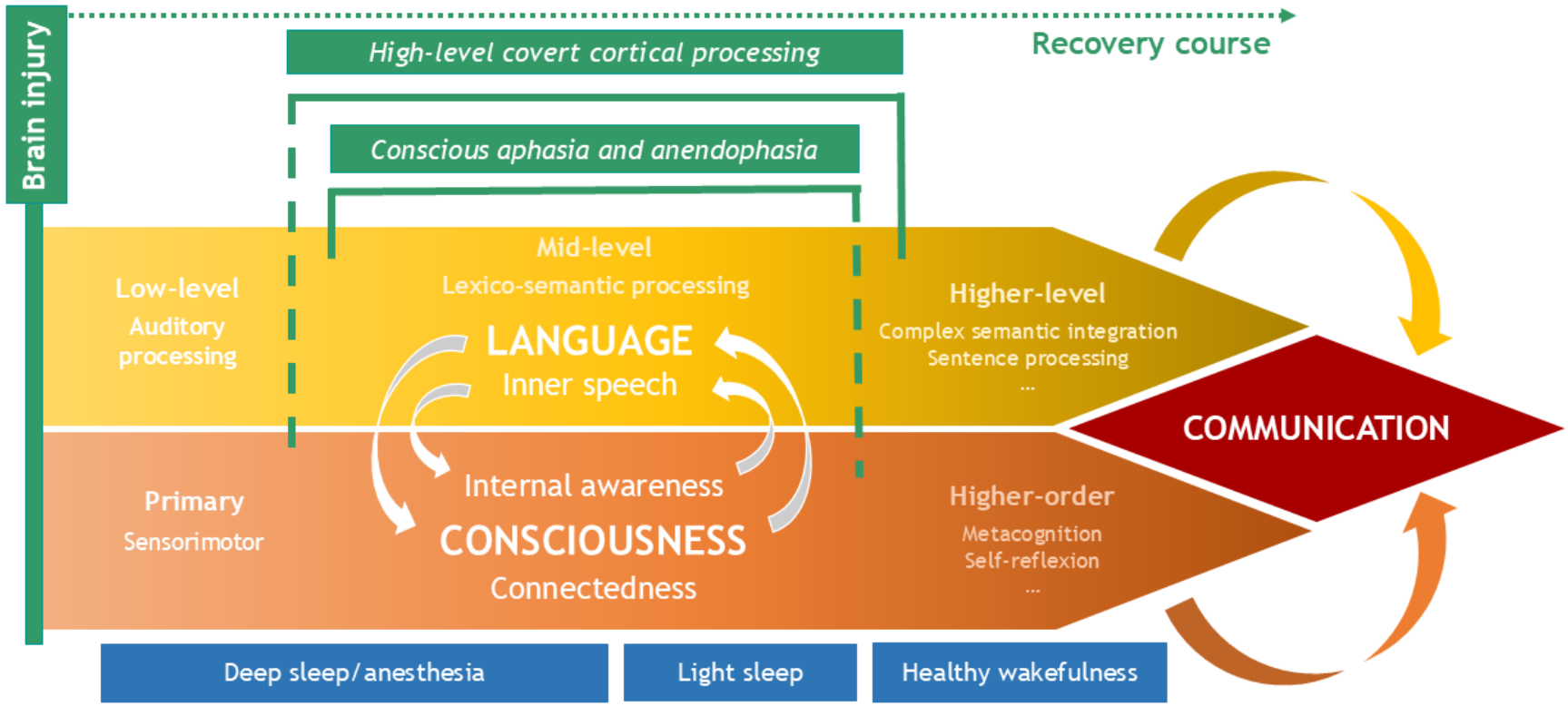

Figure 3. Evolution and interactions between language and consciousness functions. *Recent evidence supports the existence of bidirectional functional interactions between language and consciousness systems. Notably, there are strong associations between neural recovery trajectories of language and consciousness state. Clinical and cognitive research also highlights apparent dissociations between these functions, such as conscious aphasia, anendophasia, and high-level covert cortical processing. Most studies suggest that greater complexity in language integration corresponds to higher states of consciousness. Additionally, language and inner speech may play a crucial role in supporting the emergence of higher-order conscious thought. Ultimately, both functions influence communicative abilities.*