

EFFECT OF TACTILE STIMULATION IN DISORDERS OF CONSCIOUSNESS: A SYSTEMATIC REVIEW

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Abstract

Background: Disorders of consciousness (DoC) represent a major challenge in neurorehabilitation. Sensory stimulation, particularly tactile stimulation, has been proposed as a therapeutic intervention to enhance arousal and awareness in these patients.

Objective: This systematic review aimed to evaluate the effectiveness of tactile stimulation interventions in patients with DoC.

Methods: A systematic search of the literature identified 25 studies published between 1989 and 2025 investigating tactile stimulation in these patients. Data were extracted on the types of tactile interventions, methodologies, frequency, duration, and outcomes.

Results: Tactile stimulation was most commonly delivered through massage, brushing, or textured contact, targeting areas, such as the hands, arms, and face. Interventions were typically brief, administered daily over short periods, and often embedded within multimodal rehabilitation programmes. Across studies, tactile stimulation was associated with short-term improvements in behavioral indicators of consciousness and physiological responses, including heart rate and electroencephalographic activity. Interventions administered by family members appeared to yield particularly robust effects, highlighting the affective dimension of touch.

Conclusions: Current evidence supports the short-term benefits of tactile stimulation in DoC, while long-term effects remain insufficiently investigated. Future research should prioritize standardized, patient-centered protocols, with systematic follow-up and evaluation of single versus multimodal approaches, including family involvement.

Keywords

Rehabilitation; tactile stimulation; disorders of consciousness; sensory stimulation; consciousness recovery

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Introduction

Disorders of consciousness (DoC) can result from severe acquired brain injuries disrupting arousal (wakefulness) and/or awareness (self and environment perception) (1,2). In coma, both arousal and awareness are absent, with no eye-opening or voluntary responses. This state can lead to the transition to other DoC states, such as the vegetative state/unresponsive wakefulness syndrome (VS/UWS) (3). Individuals in VS/UWS have recovered arousal but do not show intentional behaviors (1,4). VS/UWS may eventually progress to a minimally conscious state (MCS), characterized by inconsistent but reproducible intentional responses, such as command following or visual pursuit (5,6). MCS can be subdivided into MCS *minus* (MCS-) and MCS *plus* (MCS+) based on the absence or presence of language processing (7). Further recovery of full consciousness may lead to the emergence from MCS (EMCS), in which individuals demonstrate consistent functional communication or purposeful object use (5). Accurate and repeated behavioral assessment is crucial for distinguishing between DoC states and identifying the predictive factors guiding clinical decisions (8), as well as for tracking individual's recovery (1,9). Rehabilitation of individuals with DoC aims to prevent secondary medical complications and promote recovery of consciousness and functional abilities (1). To enhance arousal and promote recovery in individuals with DoC, several pharmacological and neuromodulatory interventions have been explored (10,11). Drugs such as amantadine and zolpidem have shown promise in enhancing arousal and responsiveness (5,12). In patients with traumatic DoC, amantadine has been shown to accelerate functional recovery (13), particularly in the early post-injury phase (14), whereas zolpidem appears to induce behavioral improvements in only about 20% of patients (15), with clinically meaningful effects limited to a small subgroup of responders (16). Invasive stimulation protocols, such as central thalamic deep brain stimulation and non invasive brain stimulation, including repetitive transcranial magnetic stimulation (rTMS) and transcranial direct current stimulation (tDCS), are further means with potential for improving functional outcomes (2,11,17–20). Previous studies suggest that the patient's state of consciousness significantly affects the outcome of the treatment, as responsiveness appears higher for MCS (~70% after TMS, ~30% after tDCS) than for UWS/VS (~20% after TMS, ~10% after tDCS) (21). However, reported improvements are typically modest and mainly reflected by increases in CRS-R scores, whereas more complex behavioral gains (e.g., command following, visual pursuit, functional communication) appear less frequently (21–23). Finally, central thalamic deep brain stimulation is still experimental, with emerging evidence extending beyond single-case reports to small cohort studies (2,24,25). A recent meta-analysis suggests its benefits remain limited while risks are substantial, highlighting the need for rigorous patient selection (26).

Sensory stimulation has been widely explored as a rehabilitative intervention for individuals with DoC, with the aim of enhancing arousal, awareness, and cognitive functioning (27–30). Sensory stimulation programs are grounded on the concept that patients with DoC often experience sensory deprivation, which may further impair the functioning of neural circuits and limit recovery (1,31). By providing structured sensory inputs, these interventions seek to stimulate the brain, promote neural plasticity, and facilitate communication between sensory and cognitive processes (32). Sensory stimulation often involves a combined approach of tactile, auditory, visual, and olfactory modalities, whereas tactile stimulation as a standalone treatment has received comparatively less attention. Importantly, touch plays a fundamental role in human development, communication, and emotional well-being, making it a potentially powerful tool in rehabilitation (33,34). Despite this, the existing literature tends to examine tactile stimulation as part of broader, multisensory approaches rather than targeting its specific therapeutic effects (27,30,33). To date, no systematic review has specifically focused on the therapeutic potential of tactile stimulation in the

DoC population. Given the relevance of touch in activating emotional, cognitive, and sensorimotor responses (35–38), it is worth investigating its role in the rehabilitation of individuals with DoC systematically, by specifically exploring the effects of non-nociceptive tactile stimulation used for therapeutic purposes. Tactile input engages not only primary somatosensory pathways, but also broader thalamocortical and sensorimotor integration networks that are crucial for arousal and conscious processing (39). Mechanoreceptive signals are relayed through the thalamus to somatosensory cortical areas, while affective touch may additionally recruit C-tactile afferent pathways projecting through lamina I/spinothalamic pathways toward insular regions involved in interoception, salience, and emotional processing (40,41). The insula plays a key role in the processing of affective touch, supporting the idea that tactile stimulation may contribute to the reactivation of residual large-scale networks involved in behavioral responsiveness and awareness (42). Moreover, both pleasant and unpleasant tactile stimuli have recently shown to increase activity in healthy individuals' prefrontal cortex, thus confirming the widespread cerebral activation related to tactile stimulation (43).

More broadly speaking, self-generated sensory stimulation has been proposed to contribute to the organization of sensorimotor circuits across species, with related principles also explored in robotic models (44). From a rehabilitation perspective, this broader framework further supports the potential relevance of tactile stimulation, as repeated sensory input may help engage residual sensorimotor networks, promote integration between bodily signals and behavioral responses, and provide structured external input to support arousal and recovery processes in individuals with DoC (45,46).

Crucially, touch is not a unitary modality; rather, it comprises different sensory components mediated by specific receptors in the skin and in deeper tissues: mechanoreceptors (sensitive to pressure, vibration, and skin stretch), thermoreceptors (responsive to temperature changes), and nociceptors (activated by painful stimuli) (38,39). In this review, we will focus specifically on tactile stimulation mediated by mechanoreceptors, targeting its unique contributions to improve arousal and awareness in individuals with DoC. We excluded nociceptive stimuli that may induce discomfort, as we aim at assessing sensory stimulation protocols that could be easily used for rehabilitative purposes (1). To achieve this, we analyzed the methodological characteristics and effectiveness of tactile stimulation programs used in the rehabilitation of individuals with DoC, by addressing the following five questions:

a) what types of tactile stimulation have been used? b) which methodologies and body areas have been targeted? c) what are the typical frequency, duration, and number of sessions? d) what outcome measures have been employed to assess efficacy? e) what short-term and possible long-term effects have been reported?

Methods

Search strategy

The protocol of the systematic review followed the recommendations of the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) (47) and has been registered on PROSPERO (International Prospective Register of Systematic Reviews) under the registration number: CRD420251031664. For the search strategy, three databases were consulted: PubMed, PsycInfo and Cochrane. No date restrictions were applied; searches were conducted from database inception to February 2026. The search string

(adapted according to the requirements of each database) used was as follows: tactile stimul* OR touch OR tickle OR haptic OR sensory stimul* AND brain injury OR stroke OR anoxia OR minimally conscious state OR unresponsive wakefulness syndrome OR vegetative state OR disorders of consciousness OR coma.

All expressions were limited to the titles and abstracts. In the search strategy, we used the following filters: a) studies on humans; b) English language; and c) peer reviewed journals. Additional articles were identified through the references cited in the reviewed papers.

Inclusion and exclusion criteria

Inclusion criteria were: a) studies on adult and pediatric individuals with DoC due to severe acquired brain injury; b) original studies (randomized controlled trial (RCT), case study/report, observational studies) aiming to assess the effects of tactile stimulation; c) English language; and d) studies including comparisons with either no stimulation, alternative forms of stimulation, healthy control groups, individuals with other medical conditions, or within-subject comparisons before and after tactile stimulation (even if applied in a single session only).

Exclusion criteria were: a) studies evaluating only motor outcomes without assessing consciousness-related behavioral or cognitive responses (e.g., arousal, awareness); b) studies based exclusively on brain (e.g., transcranial or direct cortical stimulation) or electrical nerve stimulation without a tactile component; and c) studies including individuals with premorbid neurologic or psychiatric disorders.

We excluded studies in which the intervention was primarily physiotherapy or motor – proprioceptive rehabilitation, because tactile stimulation in these protocols is not delivered as a distinct sensory intervention and the effects on arousal/ awareness cannot be disentangled from concurrent motor and proprioceptive mechanisms.

This review was structured around the following PICO question: Population (P): adult and pediatric individuals with DoC following acquired brain injury; Intervention (I): tactile stimulation (e.g., massage, brushing, contact with textures); Comparator (C): no stimulation, alternative forms of stimulation, within pre/post comparisons, or healthy control groups; Outcome (O): changes in behavioral and neurophysiological responses related to arousal and awareness.

Study selection

A total of 4026 articles were found after the initial search across the three databases. After the removal of duplicate articles (504), unique records were uploaded to the Rayyan QCRI (Doha, Qatar) screening system, and the titles and abstracts of all articles were independently screened by two independent reviewers in accordance with the PRISMA guidelines (47). Full-text screening was then performed on 117 articles. Additional six studies were included manually from articles references after the full-text screening. Any disagreement was resolved with an arbitrator. The PRISMA flow diagram in Figure 1 illustrates the study selection process.

Data extraction

From each selected study, the following data were extracted: authors, study design, participant sample, etiology, setting, type of controls, measures (behavioral and neurophysiological), comparisons, type of intervention, outcome and main findings.

Quality assessment

The quality of evidence (QoE) for each included study was assessed by pairs of independent reviewers (S.A., A.M., F.P., L. S.) using the Newcastle-Ottawa Scale (NOS) for cohort and case-control studies (48) modified to the study's purposes (see Supplementary Files). The NOS evaluates studies based on three broad categories: selection of study groups, comparability of the groups, and ascertainment of the outcome of interest. Studies could be rated up to 10 stars, with higher scores indicating better quality. In cases of discrepancies between reviewers, discussions were held to reach consensus.

Results

Twenty-five studies, published from 1989 to 2025, met the inclusion criteria and were included in the systematic review (Figure 1). These comprised randomized controlled trials ($n = 8$), between-subject designs without randomization ($n = 8$), within-subject designs ($n = 5$), and one study each using an interrupted time series, an observational prospective design, an ABAB withdrawal design, and a retrospective design. The total number of the participants included was 1029. The main characteristics of the included studies are summarized in Table 1. A more in-depth description of each included study is provided in a Supplementary File reporting the specific methodologies, interventions, and outcomes related to tactile stimulation.

Quality evaluation

The cumulative QoE across the included studies was deemed satisfactory (Table 1). Most studies received a score of 5–6, indicating a satisfactory rating (46,49–56). Eight studies achieved a score of 7–8, reflecting good quality (57–64), whereas two studies were rated as very good (65,66), due to their robust methodology and clear statistical reporting. Six studies scored 3–4, which suggests low quality due to methodological limitations, such as imprecision in participants sampling, inadequate description of the tactile intervention, and statistical weaknesses (67–72). In summary, of the 25 reviewed studies, 2 were judged to be of very high quality, 8 were of good quality, 9 were of moderate quality, and 6 were rated as low quality. Although the quality of these last studies was lower, their findings are consistent with the results of higher-quality studies, suggesting the robustness of the overall conclusions.

Characteristics of the included studies

In most studies, tactile stimulation was part of a multidimensional sensory stimulation protocol (46,49–56,59–61,63,64,66–70,72). In three studies, tactile stimulation was combined with auditory stimulation (57,58,65), and was unimodal in two studies (62,71). Twenty-three studies included adult participants whereas two (53,68) included pediatric participants. Most studies ($n = 17$) recruited individuals in the acute phase (<4 weeks after brain injury). A smaller number of the studies ($n = 8$) included individuals in the post-acute phase (46,57,59,72) or in chronic settings (58,67,70,71). Hotz et al. (68) recruited individuals in both acute and post-acute phases. Bonanno et al. (64) enrolled individuals in a semi-intensive care setting, although the exact time post-injury was not clearly specified. In all studies, the diagnosis was made based on internationally recognized criteria for diagnosing VS/UWS and MCS (5,73,74). Twenty-one out of the 25 included studies used the Glasgow Coma Scale (GCS, $n = 15$), the Coma Recovery Scale- Revised (CRS-R, $n = 2$) or both (GCS and CRS-R, $n = 4$) to assess the state of consciousness before and/or after tactile stimulation.

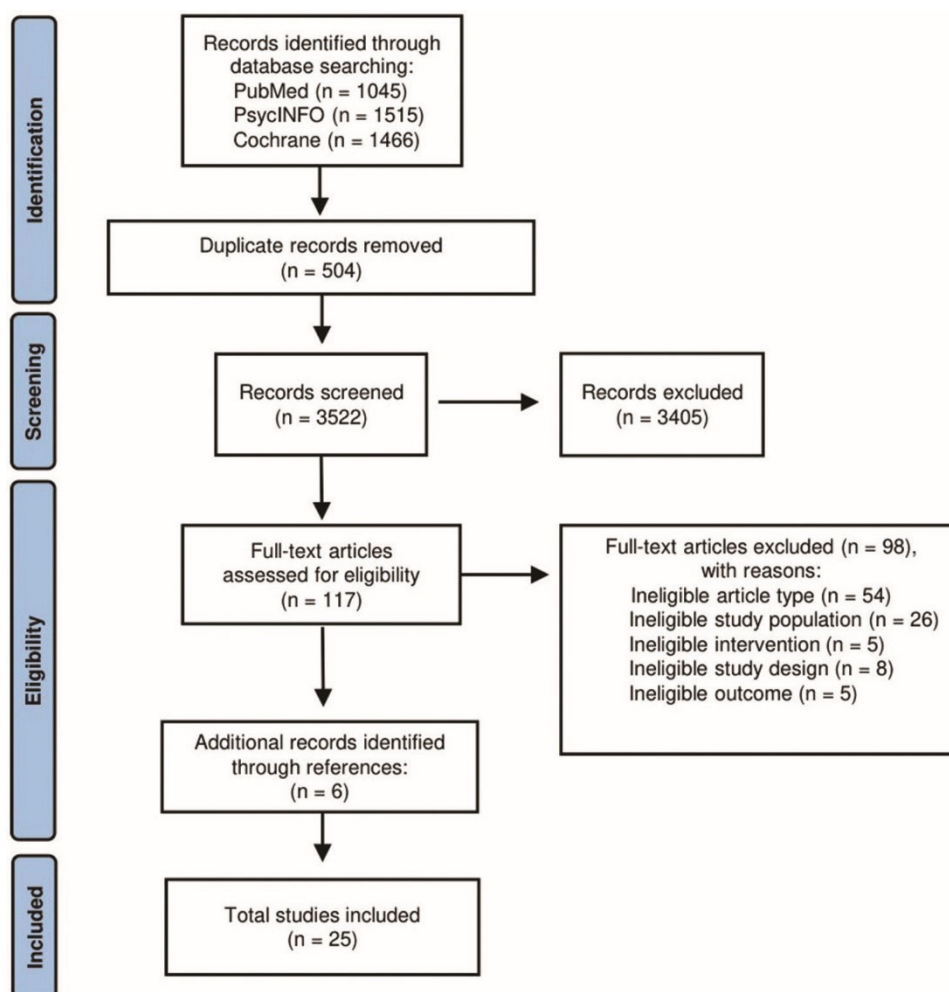


Figure 1. PRISMA flow diagram of the study selection process.

Although the GCS is a standardized and widely used clinical tool, it has limited sensitivity in distinguishing between different DoC compared with more specific behavioral assessments such as the CRS-R (4). Several studies referred to participants as ‘comatose’ (49,52,54,55,57,62,65,69), often using the term broadly to describe individuals with a GCS score below 8, without applying standardized behavioral assessments. As a result, it remains unclear whether these participants were truly in a coma or already in VS/UWS or MCS. The remaining four studies did not use either the GCS or the CRS-R, but relied on other standardized tools, used elsewhere alongside the GCS and/or CRS-R: the Level of Consciousness (LoC) (72), the Rancho Los Amigos Levels of Cognitive Functioning Scale (LCF; RLAS) (55,64,68,70); the Western Neuro Sensory Stimulation Profile (WNSSP) (61), the Disability Rating Scale (DRS) (71), the

Glasgow Outcome Scale – Extended (GOSE) (72), the Comprehensive Neurobehavioral Checklist (CNC) (71), the Sensory Modality Assessment and Rehabilitation Technique (SMART) (67), or the Loewenstein Cognitive Scale (LCS) (59). Sixteen studies compared outcomes in the treated participants with those of a control group of other individuals with DoC (49–57,60–66), while the remaining studies used a within-subject design with one stimulation group only (46,58,59,67–72). All the studies registered as outcome the behavioral responses to the stimulation, whereas six articles (57–59,64,68,71) also recorded neurophysiological parameters using electroencephalography (EEG), electromyography, or other physiological indices, such as heart rate, skin conductance response, temperature, respiratory rate, arterial pressure, peripheral oxygen saturation, blood sugar, and cerebral blood flow velocity.

Table 1. Main findings of the included studies (in chronological

N	Study	Study design	Patient sample (M/F)	Etiology	Setting	Type of control	Assessment	Comparison	Tactile intervention	Outcome	Main findings	NOS QoE
1.	Rader et al. (70)	Within-subject	Study 1 6 (4/2) Ranchos II/III Study 2 20 Ranchos II/III Study 3 19 Follow-up	Adult TBI	Chronic	None	GCS, RLAS	Before vs after stimulation vs follow-up	Stimulation applying light pressure and warm affective gestures twice a day, for 50 min, high/ low interpersonal contact and upright/supine position	Change in responsiveness	High interpersonal contact and upright positioning led to better responsiveness, while supine positioning with low contact had the least impact (Study 1). No improvement in general responsiveness at 3 months from stimulation (Study 3)	3
2.	Mitchell et al. (54)	Between subject	Experimental 12 (10/2) Coma Control 12 (10/2) Coma	Adult TBI	Acute	Other TBI patients	GCS	Exp. vs control	CAP; A large-gauge needle, stiff-bristled brush, sandpaper, fur, fabric, feathers, hot/cold packs, tuning fork, 5 times per 1 h	GCS score and duration of coma	Total duration for the experimental group was significantly shorter than total duration for the control group	6
3.	Oh & Seo (69)	Single experimental group of interrupted time series	5 (5/0) Coma	TBI	Acute	None	GCS	Time series, introduction and withdrawal design	Sphygmomanometer cuff for pressure, twice a day, 5 days a week, for 4 weeks, followed by a 4-week recession period	GCS score before and after stimulation	Significant increase in consciousness levels 2 weeks after starting sensory stimulation	4
4.	Hotz et al. (68)	Observational prospective study	15 (11/4) coma	Pediatric TBI/ NTBI	Acute and post-acute	None	GCS, RLAS, ABS, FIM	Before vs after stimulation	Snoezelen room, vibrating pillows, cushioned bubble tubes, tactile panel, 3 times a week for 30–40 min	Reductions in heart rate and muscle tone, and behavioral measures increased between pre and post-treatment	Heart rate, muscle tone and agitation levels decreased and behavioral measures increased between pre and post-treatment	4
5.	Karma et al. (53)	RCT, between subject	Experimental 30 (21/9) Coma Control 30 (22/8) Coma	Pediatric NTBI	Acute	Other NTBI patients	GCS, APVU	Before vs after stimulation vs control	Massage w/ and w/o oil, five times in a day for 2 weeks	GCS and APVU score	General improvement for the experimental group after two weeks of stimulation compared to controls	6
6.	Wijnen et al. (72)	Longitudinal within-subject	16 (10/6) VS/ UWS	Adult TBI	Post-acute	None	LoC, WNSSP, DRS, GOSE	Before vs after stimulation, vs follow-up	Spoon, comb, or pencil, on the mouth	Increased DRS and LoC scores, higher skin conductance and heart rate variability.	After the stimulation period, sympathetic activity was higher and parasympathetic activity was lower, and improved consciousness levels	4
7.	Keller et al. (58)	Within-subject	18 (11/7) PVS	Adult TBI	Chronic	None	GCS	Before vs during vs after stimulation	Massage of the left/right arm, from the wrist to the shoulder, 5 min +5 min rest	EEG peak frequencies and mean HR, EMG and SCR activity	Significant difference in EEG peak frequency between the baseline and tactile stimulation conditions at positions Fz and T3. Significant increases of SCR, EMG and HR in tactile stimulation	7
8.	Abbasi et al. RCT (49)	RCT	Experimental 25 (22/3) Coma Control 25 (21/4) Coma	Adult TBI	Acute	Other TBI patients	GCS	Before vs after stimulation/ exp. vs control	Gentle touching and holding hands and face. 15 min daily for 6 days	GCS score	Significant increase in consciousness levels in experimental group compared to controls	6
9.	Urbenjaphol et al. (66)	RCT	Experimental 20 (14/6) Coma Control 20 (14/6) Coma	Adult TBI	Acute	Other TBI patients	GCS, SMART	Before vs after stimulation/ exp. vs control	Warm and cold water, wet towels and soap, massage w/body lotion on head, face, trunk, and extremities, for 30 min, 14 consecutive days	GCS and SMART scores	Significant improvement in experimental group in GCS and SMART scores. The SMART scores of the tactile and auditory modalities were slightly higher than the scores of the other sensory modalities	9

N	Study	Study design	Patient sample (M/F)	Etiology	Setting	Type of control	Assessment	Comparison	Tactile intervention	Outcome	Main findings	NOS QoE
10	Mandeep et al. (60),	Between subject	Experimental 15 Coma Control 15 Coma	Adult TBI	Acute	Other TBI patients	GCS, CRS-R	Before vs during stimulation/ exp. vs control	Brush, cloth textures, sandpapers, cotton balls applied for 5 s, 2 times, with 3 s break on R/L upper/lower extremities twice a day for 2 weeks	CRS-R, GCS scores	Experimental group had significantly higher score on GCS and CRS-R than controls	7
11.	Megha et al. (61)	Between subject	Group A: 10 Coma Group B: 10 Coma Control 10 Coma	Adult TBI	Acute	Other TBI patients	GCS, WNSSP	Group A vs Group B vs control, before vs after stimulation	Stiff bristled brush, sandpaper, fur, fabric, hot and cold packs, for 1 s, every 3 s on dorsum of each hand Group A: 5 sessions a day for 20 min; Group B: 2 sessions a day, for 50 min. 5 day per week for 2 weeks	GCS and WNSSP scores	Both Groups A and B had significantly higher scores on GCS and WNSSP than controls. Multimodal coma stimulation 5-times daily for 20 min per session (Group A) was better than twice daily for 50 minutes per session (Group B)	7
12.	Moattari et al. (55)	Double-blind RCT	Group A: 20 (15/ 5) Coma Group B: 20 (18/2) Coma Control 20 (17/3) Coma	Adult TBI	Acute	Other TBI patients	GCS, WNSSP, RLAS	Before vs after stimulation/ Group A vs Group B vs contro	Gentle touch, soft brush, comb, spoon on shoulder, face, lips, for 5 min, twice daily for 7 days	GCS, WNSSP and RLAS scores	Stimulation delivered from family members led to significantly higher GCS, RLA and WNSSP scores after 7 days than the two other groups	6
13.	Deiva et al. (50)	Between subject	Experimental 15 Coma Control 15 Coma	Adult TBI	Acute	Other TBI patients	GCS, CRS-R	Before vs after stimulation/ experimental vs control	Cotton ball and gentle touch for 10 s on R/L upper/lower extremities. Twice daily for 14 days	GCS, CRS-R scores	Higher GCS and CRS-R scores for experimental group on 14th day compared to controls	5
14.	Sargolzaei et al. (56)	RCT, between-subject	Experimental 40 (18/22) Coma Control 40 (15/25) Coma	Adult TBI	Acute	Other TBI patients	GCS, SMART	Before vs during stimulation/ experimental vs control	Massage w/olive oil on limbs, washing hands with cold/hot water, once a day 5–10 min for 14 days	SMART score	SMART score significantly increased in the experimental group compared to controls. Greatest improvement for auditory modality, tactile had the least improvement	6
15.	Salmani et al. (63)	Double-blind RCT	Experimental 30 (22/8) Coma Placebo 30 (24/6) Coma Control 30 (22/8)	Adult TBI	Acute	Other TBI patients	GCS, CRS-R, APACHE	Before vs after stimulation/ experimental vs placebo vs control	Caresses and gentle stroke on face and body, 30–45 min, twice a day for 7 days	GCS and CRS-R scores	Experimental group had significantly higher score on GCS and CRS-R than placebo and controls	7
16.	Cheng et al. (46)	Withdrawal (ABAB)	29 11 VS/UWS 18 MCS	Adult TBI/ NTBI	Post-acute	None	CRS-R	Before vs after stimulation	Pressure w/fingertips on R/L arm, from shoulder to the wrist. 20 min twice a day, 3 times a week for 16 weeks	CRS-R score	CRS-R scores improved during stimulation phases, especially in MCS; no change during withdrawal phases	6
17.	Bahonar et al. (65)	RCT	Group 1 30 (26/ 4) Group 2 30 (22/8) Group 3 30 (24/6) Controls 30 (26/4) All Coma	Adult TBI	Acute	Other TBI patients	GCS	Before vs after stimulation over two weeks Group 1 (nature sounds) vs Group 2 (reflexology) vs Group 3 (combined) vs control	Foot sole reflexology massage w/oil, pressure on feet, 30 min twice a day for 2 weeks	GCS score at baseline, 1 week, and 2 weeks	All experimental groups showed significantly higher GCS scores at 1 and 2 weeks compared to the control group. No significant differences were found among the experimental groups in the time taken to regain full consciousness	9

N	Study	Study design	Patient sample (M/F)	Etiology	Setting	Type of control	Assessment	Comparison	Tactile intervention	Outcome	Main findings	NOS QoE
18.	Deshpande et al. (51)	Between-subject	Experimental 15 (11/4) Coma Control 15 (10/5) Coma	Adult TBI	Acute	Other TBI patients	GCS, WNSSP	Before vs after stimulation/ exp. vs control	Light strokes, massage on back, upper limbs, 10 min twice daily, 5 days/per week for 6 weeks	WNSSP score	Experimental group showed significant improvement on WNSSP compared to controls	5
19	Salehi et al. (62)	Between subject	60 in 4 Groups (42/18) Coma, 3 experimental + control	Adult TBI	Acute	Other TBI patients	GCS, RASS	Before vs after stimulation/ exp. vs control	Gentle massage on hands and feet reflexology (separate and together) for 5 min twice a day for 5 days	GCS score and vital signs	Both foot reflexology and tactile stimulation, especially when combined significantly improved the GCS scores and vital signs in patients with TBI	8
19	Salehi et al. (62)	Between subject	60 in 4 Groups (42/18) Coma, 3 experimental + control	Adult TBI	Acute	Other TBI patients	GCS, RASS	Before vs after stimulation/ exp. vs control	Gentle massage on hands and feet reflexology (separate and together) for 5 min twice a day for 5 days	GCS score and vital signs	Both foot reflexology and tactile stimulation, especially when combined significantly improved the GCS scores and vital signs in patients with TBI	8
20.	Venturella et al. (71)	Within-subject	22 (13/9) VS/UWS	Adult TBI	Chronic	None	CNC, DRS	Before vs after stimulation	Wrist grasping (pleasant) and ice pack (unpleasant) for 10 s	EEG power spectrum changes	Both pleasant/unpleasant stimuli increased delta band activity, especially in parietal regions during the unpleasant ones. Pleasant stimulation decreased the alpha activity in the L frontal regions compared to unpleasant ones	4
21.	da Conceição Teixeira et al. [67]	Retrospective study	10 (8/2) VS/UWS 25(20/5) MCS	Adult TBI/ NTBI	Chronic	None	SMART	MCS vs VS/UWS based on repeated SMART assessments	Touching, rubbing body areas, such as the hands, feet, or limbs	SMART score	MCS showed higher mean scores in various sensory modalities during stimulation compared to VS/UWS	3
22.	Faozi et al. (52)	Between subject	Experimental 2 (16/6) Coma Control 22 (11/11) Coma	Adult TBI	Acute	Other TBI patients	GCS	Before vs after stimulation/ experimental vs control	Gentle massage on shoulder, back of the hand, for 5 min 5 times daily for 5 days	GCS score	Experimental group showed a significant increase in GCS scores compared to controls	6
23.	Lehrer et al. (59)	Within-subject	35 (28/7) 10 VS/UWS 25 MCS	Adult TBI/ NTBI	Post-acute	None	LCS	Before vs after stimulation	Snoezelen room, objects with different textures, such as soft, rough, warm/cold, for 1 min	HR, CBFV, LCS scores	Snoezelen stimulation induced improvements in communication and physiological measures (HR, CBFV) in MCS. No significant physiological changes were observed in VS/UWS	7
24.	Ahmed et al. (57)	RCT	60 MCS (38/22) Experimental 30 Control 30	Adult TBI	Post-acute	Other TBI patients	GCS, CRS-R	Before vs after stimulation, exp. vs control	Gently caresses on hands, head, face, and limbs, 15 min once daily for 14 days	GCS, CRS-R scores and vital signs	The experimental group showed significant improvements in GCS and CRS-R scores compared to the control group	8
25.	Bonanno et al. (64)	Between-subject	20 MCS (15/5) Experimental 10 Control 10	Adult TBI/ NTBI	Post-acute	Other TBI/ NTBI patients	CRS-R, LCF	Before vs after treatment, exp. vs control	Gentle touch stimulation, 60 min/session, 3 times/week for 24 weeks	CRS-R, LCF scores, HR, P300 latency	The experimental group showed significant improvements in neurophysiological (P300 latency, HR) and clinical outcomes (CRS-R, LCF) compared with the control group	7

Legend: ABS = Agitated Behaviour Scale; APACHE = Acute Physiology and Chronic Health Evaluation; APVU = Alert, Voice, Pain, Unresponsive Scale; CAP = Coma Arousal Procedure; CBFV = cerebral blood flow velocity; CRS-R = Coma Recovery Scale-Revised; DRS = Disability Rating Scale; EEG = electroencephalography; EMG = electromyography; FIM = Functional Independence Measure; GCS = Glasgow Coma Scale; GOSE = Glasgow Outcome Scale Extended; HR = Heart rate; LCF = Level of Cognitive Functioning; LoC = Level of Consciousness; MCS = Minimally Conscious State; NTBI = Non Traumatic Brain Injury; PVS = Persistent Vegetative State; QoE = Quality of Evidence; RCT = Randomized Controlled Trial; R/L = right/left; RAS = Ranchos Los Amigos Scale; SCR = skin conductance response; SMART = Sensory Modality Assessment and Rehabilitation Technique; TBI = Traumatic Brain Injury; VS/ UWS = Vegetative State/Unresponsive Wakefulness Syndrome; WHIM = Wessex Head Injury Matrix; WNSSP = Western Neuro Sensory Stimulation Profile.

No explicit overlap of study populations was identified across the included studies based on the information reported in the original articles. However, because recruitment sites and periods were not always described in sufficient detail, a partial overlap between samples cannot be entirely excluded.

In the following paragraphs, we will address the five research questions outlined above.

Types of tactile stimulation applied to the participants

Various kinds of tactile stimulation were applied (Table 2). Specifically, tactile interventions included: (i) manual touch- based stimulation, such as light pressure, warm affective gestures, gentle touching, and hand-holding, massages with oil or body lotion, caresses, and gentle touch (e.g., 46, 49, 51-53, 56- 58, 62- 67, 70); (ii) object-mediated stimulation, using items with different textures or shapes, such as a large-gauge needle, stiff-bristled brush, sandpaper, fur, fabric, feathers, tuning fork, spoon, comb, pencil, cotton balls, cloth textures, soft brush, and tactile panels (e.g., 50, 54, 55, 59-61, 68, 72); (iii) pressure- or temperature-based stimulation, including sphygmomanometer cuff pressure, warm and cold water, wet towels, hot/cold packs, and ice packs, to evoke different sensory responses (e.g., 54, 56, 59, 61, 66, 69, 71); and (iv) tactile input embedded within enriched multisensory environments, such as Snoezelen-based protocols involving vibrating pillows, cushioned bubble tubes, and tactile panels (e.g., 59, 68). These interventions represent the full range of stimulation approaches used in the studies. Some of them contributed to more than one category because they combined multiple tactile modalities within the same protocol.

Methodology used and stimulated area

Most studies applied tactile stimulation in controlled settings, often in Intensive Care Unit (ICU) environments or specialized Snoezelen rooms (59,68). Tactile stimulation was usually applied to areas like the hands, arms, shoulders, and face. For example, Keller et al. (58) focused on massaging the arm from wrist to shoulder, while Salehi et al. (62) targeted the hands, and Moattari et al. (55) focused on the face (including lips) and shoulders. Similarly, Bonanno et al. (64) applied gentle touch manually to different body sites, including the wrists, hands, arms, and legs, using bilateral light skin-to-skin pressure. A detailed description of the target areas for each study is reported in Table 1. Methodologically, these interventions involved manual techniques such as massage or the application of objects (such as soft brushes, sponges, or textured fabrics) designed to stimulate tactile receptors, often delivered by nurses, family members, or therapists.

Frequency, duration, and number of tactile stimulation sessions

The frequency and duration of tactile stimulation varied across studies. The number of sessions ranged from one to multiple times daily over periods extending from a few days to several weeks, reflecting the need for consistent and repeated exposure to tactile input. In Salehi et al. (62), individuals received tactile stimulation for 5 minutes, twice daily, over 5 consecutive days. Moattari et al. (55) implemented 30-minute stimulation sessions twice a day for 7 days. Lehrer et al. (59) applied tactile stimulation for 1 minute per stimulus, in sessions involving multiple sensory modalities. Bonanno et al. (64) adopted a longer rehabilitation schedule, consisting of 60-minute sessions delivered three times per week for 24 consecutive weeks within a structured multisensory program, highlighting the considerable variability in treatment intensity and duration across studies. Megha et al. (61) demonstrated that multimodal stimulation in individuals with coma, particularly when administered at higher frequency (5 sessions/day for 20 min), was

more effective in improving consciousness levels than lower- frequency (2 sessions/day for 50 min) stimulation or conventional physiotherapy. The authors emphasize that short, frequent sessions are more beneficial for recovery than longer, less frequent ones.

Table 2. Types of tactile stimulation (non-mutually exclusive categories) used across the included studies ($n = 25$).

Types of tactile stimulation	Number of studies	Percentage	References
Manual touch-based stimulation (<i>e.g., light pressure, warm affective gestures, hand-holding, massage, caresses, gentle touch</i>)	15	60%	46, 49, 51-53, 56-58, 62-67, 70
Object-mediated stimulation (<i>e.g., textured items, brush, sandpaper, fur, tuning fork, spoon, comb, pencil, tactile panels</i>)	8	32%	50, 54, 55, 59-61, 68, 72
Pressure- or temperature-based stimulation (<i>e.g., cuff pressure, warm/cold water, wet towels, hot/cold packs, ice packs</i>)	7	28%	54, 56, 59, 61, 66, 69, 71
Tactile input embedded in enriched multisensory environments (<i>e.g., Snoezelen-based protocols with vibrating pillows, bubble tubes, tactile panels</i>)	2	8%	59, 68

Note. Studies could contribute to more than one category when interventions combined multiple tactile modalities; therefore, percentages do not sum to 100%.

Tools for evaluating the efficacy of tactile stimulation

The most used tools to evaluate effectiveness of the tactile stimulation were the GCS (74) and the CRS-R (73). Both scales were used in multiple studies (Table 3) to track changes in consciousness states throughout the interventions. Most studies used the GCS alone for assessment (49,52,54,58,65,69), whereas others used it in combination with additional scales: the CRS-R (50,57,60,63), the Acute Physiology and Chronic Health Evaluation (APACHE) (63), the SMART (56,66), the WNSSP (51,55,61), the Rancho Los Amigos Levels of Cognitive Functioning Scale (LCF/RLAS) (55,68,70), the Alert, Voice, Pain, Unresponsive Scale (APVU) (53), the Richmond Agitation- Sedation Scale (RASS) (62), and the Agitated Behaviour Scale and Functional Independent Measure (FIM) (68). Bonanno et al. (64) used the CRS-R in combination with the Level of Cognitive Functioning scale (LCF). Some studies used a single scale, including CRS-R in Cheng et al. (46), SMART in da Conceição Teixeira et al. (67), and the LCS in Lehrer et al. (59). Wijnen et al. (72) instead used multiple tools, including the LoC, the GOSE, the WNSSP, and the DRS. Venturella et al. (71) used the Comprehensive Neurobehavioral Checklist (CNC) and the DRS. Other studies used the WNSSP to assess various sensory modalities, including tactile stimulation. Deshpande et al. (51) used the WNSSP to evaluate the effectiveness of choice-based sensory stimulation applied by family members. The study showed significant improvements in tactile responses, with the WNSSP scores improving from the pre-treatment to the post-treatment in the intervention group. The WNSSP was effective in measuring how tactile interventions contributed to increased arousal and cognitive functioning. The SMART was another prominent scale used to assess sensory function. Sargolzaei et al. (56) applied the SMART scale to measure the efficacy of a structured sensory stimulation program, including tactile interventions like massage and passive limb movements. The study showed significant improvements in SMART scores in the intervention group, with tactile stimulation contributing notably to sensory recovery in individuals with traumatic etiology.

In addition, Venturella et al. (71) and Keller et al. (58) employed EEG and physiological measures (*e.g., heart rate, skin conductance*) to assess the immediate impact of tactile stimulation on brain and autonomic responses, while Bonanno et al. (64) assessed heart rate and P300 latency in addition to CRS-R and LCF scores, showing improvements in both clinical and neurophysiological outcomes.

Table 3. Assessment tools used to evaluate the state of consciousness in the included studies ($n = 25$).

Assessment tools	Number of studies	Percentage	References
GCS only	6	24%	49, 52, 54, 58, 65, 69
CRS-R only	1	4%	46
GCS + CRS-R	4	16%	50, 57, 60, 63
GCS + other standardized scales (RLAS, APVU, SMART, WNSSP, RASS, ABS/FIM)	9	36%	51, 53, 55, 56, 61, 62, 66, 68, 70
CRS-R + other standardized scales (LCF)	1	4%	64
Other standardized scales without GCS and CRS-R (LCS, SMART, DRS, GOSE, CNC, LoC)	4	16%	59, 67, 71, 72

Legend: GCS = Glasgow Coma Scale; CRS-R = Coma Recovery Scale-Revised; RLAS/LCF = Ranchos Los Amigos Scale/Level of Cognitive Functioning; WNSSP = Western Neuro Sensory Stimulation Profile; SMART = Sensory Modality Assessment and Rehabilitation Technique; LCS = Loewenstein Cognitive Scale; DRS = Disability Rating Scale; GOSE = Glasgow Outcome Scale Extended; LoC = Level of Consciousness; APVU = Alert, Voice, Pain, Unresponsive Scale; RASS = Richmond Agitation-Sedation Scale; ABS = Agitated Behaviour Scale; FIM = Functional Independent Measure.

Short- and long-term effects of the tactile stimulation

Most studies (84%) reported improvements in behavioral measures of consciousness following tactile stimulation (Table 4). A smaller proportion of studies (24%) also reported physiological or neurophysiological changes, while only a limited number of studies (20%) included follow-up assessments to evaluate longer-term effects. About short-term effects, defined as physiological and behavioral outcomes measured immediately or within a few days after the intervention, studies consistently demonstrated that tactile stimulation led to significant improvements in consciousness states. For instance, Salehi et al. (62) showed a significant increase in GCS scores after just 5 days of intervention. Similarly, in Moattari et al. (55), tactile stimulation administered by both family members and nurses led to marked improvements in GCS and cognitive recovery scores after 7 days. Similarly, Bonanno et al. (64), although based on a longer treatment schedule, showed significant post-treatment improvements in both clinical and neurophysiological outcomes, including higher CRS-R and LCF scores, reduced heart rate, and shorter P300 latency in the experimental group compared with controls. Long-term effects were less frequently addressed, but Keller et al. (58) noted that although immediate physiological responses (like increased EEG activity), but no formal long-term follow-up was reported. Nonetheless, Ahmed et al. (57) suggested that family involvement in tactile stimulation could foster sustained improvements in consciousness and cognitive function over time.

Table 4. Summary of outcomes reported in the included studies ($n = 25$) and percentage of studies reporting improvements for each type of outcome.

Outcome category	Number of studies	Percentage	References
Behavioral improvement in consciousness measures	21	84%	46, 49-57, 60-66, 68-70, 72
Physiological/neurophysiological outcomes (EEG, HR, SCR, EMG, etc.)	6	24%	58, 59, 64, 68, 71, 72
Follow-up assessments evaluating long-term outcomes	5	20%	46, 53, 69, 70, 72
Studies reporting sustained or improved outcomes at follow-up	3	12%	53, 69, 72
Studies reporting limited or inconclusive long-term effects	2	8%	46, 70

Legend: EEG = Electroencephalography; HR = Heart Rate; SCR = Skin Conductance Response; EMG = Electromyography.

Several studies included follow-up evaluations to assess the long-term effects of tactile and sensory stimulation on individuals with DoC, or those described as comatose based on GCS criteria. Cheng et al. (46) found that MCS individuals showed improvements during the intervention phases, but these gains diminished during withdrawal periods, suggesting the need for sustained stimulation. Rader et al. (70) conducted a three-month follow-up, where short-term responsiveness improved, but long-term outcomes showed minimal sustained benefits, indicating the need for more continuous therapy. In Oh & Seo (69),

follow-ups after each cycle of sensory stimulation showed that initial gains in consciousness decreased over time, but after repeated interventions, the improvements were more lasting. Wijnen et al. (72) followed participants for up to 3–4 years, finding that while short-term improvements in behavioral and autonomic responses were noted, most individuals still exhibited some disability, though a few achieved moderate recovery. Similarly, Karma et al. (53) found that early sensory stimulation led to better recovery outcomes during the two-week follow-up compared to delayed intervention, underscoring the importance of timely intervention for more effective long-term results.

Discussion

The objective of the present review was to gather and analyze evidence from the studies using tactile stimulation as a therapeutic intervention in individuals with DoC. Specifically, this review aimed to assess whether and how tactile stimulation could enhance arousal and awareness in clinical rehabilitation, contributing to better outcomes. The main characteristics of tactile stimulation interventions and the overall findings of the included studies are summarized in Figure 2.

Overall, the studies on tactile stimulation within sensory stimulation programs for individuals with DoC consistently demonstrate that tactile interventions can be effective in improving recovery of consciousness and associated physiological and behavioral outcomes. Although tactile stimulation was often part of a broader multimodal approach, its contribution was significant, particularly when applied early and with specific methods aimed at engaging sensory and motor responses.

A key interpretative aspect when discussing tactile stimulation in DoC concerns the distinction between arousal and awareness, two partially dissociable components of consciousness with different clinical implications. Arousal refers to the level of wakefulness/vigilance (i.e. eye opening), whereas awareness refers to the presence of conscious content and purposeful, reproducible responses to external or internal stimuli (5,73,75,76). This distinction is particularly relevant in the present review because improvements in arousal in patients described as comatose may represent a major clinical step, while in patients with MCS changes in arousal alone are less informative unless accompanied by behavioral signs indicative of awareness.

Several included studies reported positive short-term effects of tactile stimulation. However, only two studies (62,71) have specifically focused on unimodal tactile stimulation. Salehi et al. (62) demonstrated that unimodal tactile stimulation of the hands significantly improved GCS scores in comatose individuals with traumatic brain injury (TBI), with even greater enhancements observed when combined with foot reflexology, positively impacting on consciousness and physiological outcomes. Venturella et al. (71), in contrast, observed that tactile stimulation can elicit an increased frontal and parietal activation as well as unpleasant thermal stimulation, although pain-related thermal stimulation (referred here only as an unpleasant comparator to contrast stimulus valence within cutaneous somatosensory input) was associated with stronger responses. These findings suggest that tactile stimulation alone can elicit measurable cortical responses even in severely impaired patients. However, such responses should be interpreted cautiously: rather than directly reflecting awareness, they may indicate preserved sensory discrimination or stimulus-response processing in response to affectively distinct stimuli, and are not necessarily related to conscious processing.

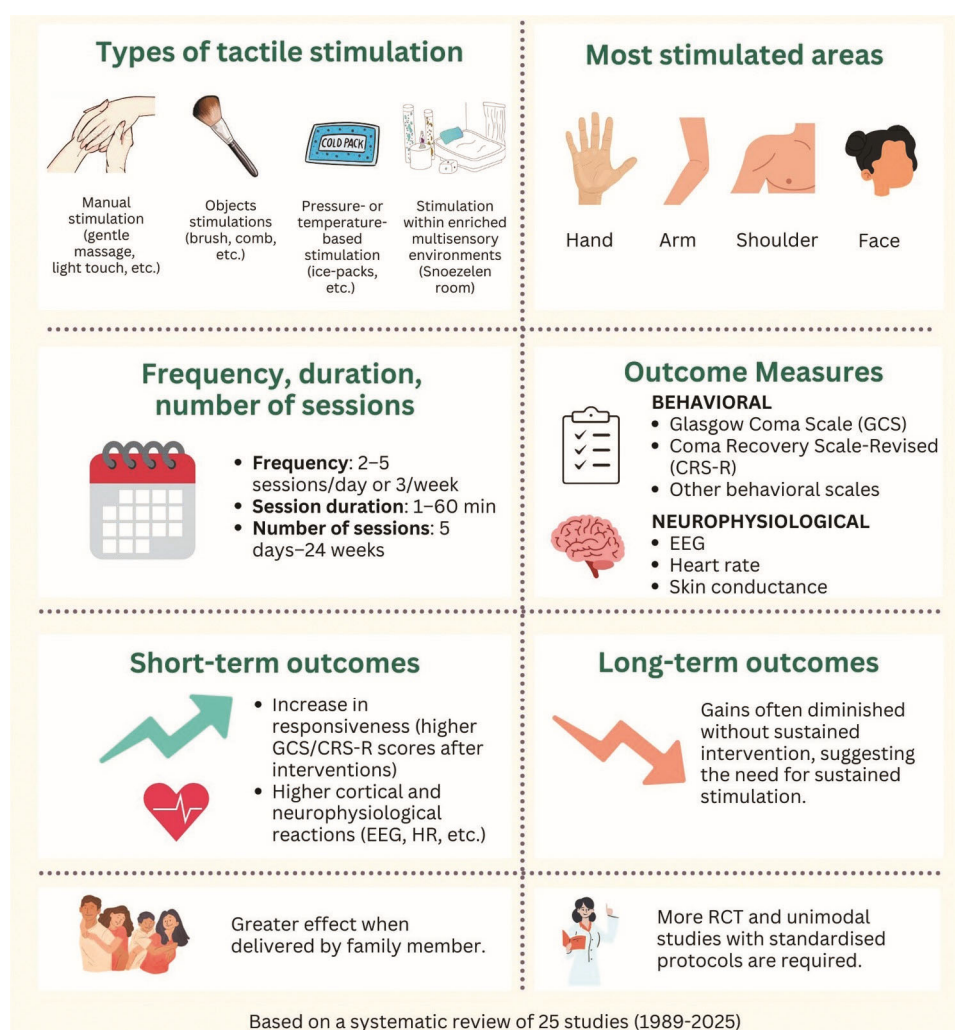


Figure 2. Summary of the main characteristics and findings of tactile stimulation interventions in disorders of consciousness.

While these results appear promising, they are limited to only two studies that have investigated the specific impact of unimodal tactile stimulation, as most interventions were applied within broader multimodal programs. This is an important aspect that requires further investigation through more specific studies focusing solely on tactile stimulation. Indeed, a recent study on healthy participants demonstrated that tactile stimulation, in particular pleasant touch stimulation, can significantly enhance activity in the prefrontal cortex, as measured by functional near-infrared spectroscopy (43). These findings highlight the ability of pleasant tactile stimuli to engage high-order cortical areas involved in affective and cognitive processing. Although these results were obtained in a non-clinical population, they offer a promising starting point for exploring the potential of tactile stimulation in modulating neural activity and supporting consciousness recovery in individuals with DoC.

The other studies included in this review suggest that tactile stimulation, when combined with other sensory modalities, can contribute to inducing significant benefits in terms of arousal and awareness. Indeed, tactile stimulation appears to work synergistically with other sensory modalities in enhancing responsiveness and consciousness recovery. For instance, Rader et al. (70) and Oh et al. (69) demonstrated that tactile interventions, such as light pressure, led to short-term improvements in GCS scores. Notably, in studies relying primarily on the GCS and/or broadly defined ‘comatose’ samples, these improvements likely

reflect changes in arousal rather than awareness per se. In this context, increases in arousal represent a clinically meaningful step, whereas in patients in MCS interpretation in terms of awareness requires concurrent evidence of purposeful, reproducible behaviors (e.g., on CRS-R items) (3,73). Similarly, Wijnen et al. (72) and Urbenjaphol et al. (66) reported significant enhancements in behavioral and autonomic responses. Moreover, Megha et al. (53) and Deiva et al. (50) found that higher frequencies of tactile stimulation substantially improved GCS and CRS-R scores. Notably, Urbenjaphol et al. (66) and Deiva et al. (50) also observed that combining tactile stimulation with auditory or visual inputs resulted in more pronounced improvements, suggesting that a multimodal approach may be more effective in enhancing consciousness than tactile stimulation alone. In particular, some studies highlighted the synergistic effects of combining tactile and auditory stimulation in enhancing consciousness and physiological responses in individuals with DoC. Indeed, Bonanno et al. (64) reported that a structured multisensory rehabilitation program including gentle touch delivered over a longer schedule (three sessions/week for 24 weeks) was associated with significant improvements in clinical outcomes (CRS-R and LCF) compared with controls, and it also documented concurrent improvements in neurophysiological indices (reduced heart rate and shorter P300 latency), suggesting that tactile stimulation embedded within a structured program may modulate both behavioral responsiveness and cortical/autonomic markers in MCS patients.

Moreover, Keller et al. (58) demonstrated that tactile stimulation significantly increased neurophysiological cortical and peripheral responses as measured by EEG, and EMG, SCR, HR, compared to baseline. Acoustic stimulation, specifically white noise, led to a significant increase in SCR and EMG, with the combination between tactile and acoustic stimulation effectively enhanced arousal levels in individuals with VS/ UWS. However, neurophysiological reactivity (including differential responses to stimulus valence) should be interpreted cautiously, as it may indicate preserved sensory processing without necessarily implying awareness. Abbasi et al. (49) found that a regular family visiting program providing both tactile and auditory stimulation significantly improved GCS scores in 'comatose' individuals, indicating that the combined effect of these modalities can more effectively enhance consciousness and responsiveness than single modalities. Bahonar et al. (65) also reported that combining nature sounds with tactile stimulation, such as foot sole reflexology, led to higher consciousness levels and faster recovery compared to either modality alone, emphasizing that integrating auditory and tactile stimuli can reduce the duration of coma and improve cognitive responses in individuals with TBI. Furthermore, Ahmed et al. (57) demonstrated that family-centered auditory and tactile stimulation significantly increased consciousness levels, reduced physiological adverse events, and shortened ICU stays in individuals with TBI, underscoring the importance of structured, frequent, and emotionally significant sensory stimulation in optimizing recovery outcomes.

The findings of this review are consistent with other studies in the literature. For example, Norwood et al. (33) conducted a systematic review focusing on the effectiveness of multimodal sensory therapy for individuals with acquired brain injury, including those with DoC. Their findings emphasized that multimodal approaches, which incorporate tactile stimulation alongside auditory, visual, and olfactory inputs, significantly enhance arousal, neuroplasticity, and cognitive outcomes compared to unimodal interventions. One of the key insights from Norwood et al. (33) was the importance of early and frequent application of sensory stimuli to maximize recovery, suggesting that integrating tactile stimulation in the acute phases of rehabilitation could prevent sensory deprivation and support long-term functional recovery. Additionally, the review pointed out that the combination of sensory modalities can create a more enriching environment, which is crucial for sustaining attention and engagement in individuals with DoC. Also Weaver et al. (30) conducted a systematic review focusing on interventions to facilitate the recovery

of consciousness following TBI, in both acute and chronic settings. Their analysis identified multimodal sensory stimulation as one of the most effective approaches for improving arousal and awareness in individuals with DoC. The review from Weaver et al. (30) emphasized the importance of personally relevant and emotionally salient stimuli, including tactile inputs that are meaningful and familiar to the participants. It also highlighted the need for standardized protocols to assess the optimal type, frequency, and duration of tactile stimulation. Moreover, the authors found that administering multimodal sensory stimulation at least twice daily resulted in more significant improvements in responsiveness compared to less frequent interventions, underlining the need for consistency and intensity in sensory-based rehabilitation strategies. These findings align with the broader understanding that tactile stimuli, together with other sensory modalities, are helpful in eliciting responsiveness and behavioral signs of awareness in individuals with DoC, especially when emotionally affective stimuli are employed. This is also in line with the results from a recent systematic review supporting that emotionally meaningful and self-referential inputs, such as one's own name or face, can significantly enhance behavioral and electrophysiological responses in individuals with DoC (77).

Along this line, another important consideration from the present review is the role of family involvement in administering tactile stimulation. Studies by Moattari et al. (55) and Salmani et al. (63) indicated that family-provided tactile interventions led to greater improvements in consciousness compared to nurse-administered stimulation. This may point to the emotional and familiar component of touch, further amplifying its impact on recovery. The presence of familiar individuals likely adds an additional layer of emotional engagement, making the tactile stimulation more effective in fostering responsiveness. A systematic review by Zuo et al. (34) demonstrated that sensory stimulation delivered by family members led to greater improvements in GCS scores, faster awakening times, and higher satisfaction rates compared to standard care. This effect was attributed to the emotional and familiar nature of touch, which may enhance oxytocin release and stimulate the autonomic nervous system, thereby facilitating neuroplastic changes and recovery.

While the immediate benefits of tactile stimulation are clear, the present review also reveals the challenge of sustaining long-term improvements. Studies such as those by Rader et al. (70) and Cheng et al. (46) demonstrated that while initial gains were promising, the absence of continuous stimulation often led to a decline in responsiveness over time. This highlights the need for structured, long-term interventions to maximize recovery potential. In this regard, Bonanno et al.'s study (64) is noteworthy because it adopted a substantially longer intervention schedule (24 weeks), and observed post-treatment improvements on both CRS-R/LCF and neurophysiological parameters. Although formal follow-up assessments were not reported, this study supports the feasibility and potential value of longer-duration, structured stimulation programs to consolidate clinical gains.

Several limitations emerged across the studies included in this review. First, the GCS was often used as the primary outcome measure; however, this scale is not sufficiently sensitive to detect subtle changes in consciousness states, especially when compared to more refined tools like the CRS-R. This limits the possibility of disentangling whether observed improvements primarily reflect enhanced arousal or more specific changes in awareness, particularly in studies where diagnostic characterization (VS/UWS vs. MCS) was not clearly established. Second, in many studies, especially in acute settings, participants were generically described as being in a 'coma,' without a formal diagnosis using standardized criteria for DoC, such as VS/UWS or MCS. This limits the diagnostic accuracy and generalizability of the findings. Moreover, in most cases, tactile stimulation was delivered as part of a multimodal program, making it difficult to isolate

its specific contribution. Few studies provided detailed reporting of the stimulation protocols (e.g., intensity, duration, timing), and only a limited number of them included long-term follow-up assessments to evaluate the persistence of effects over time. Furthermore, most studies did not report whether outcome assessments were conducted by blinded raters, raising concerns about potential assessment bias. Similarly, information regarding blinding of group allocation or data analysis was generally missing, limiting methodological rigor and increasing the risk of performance and detection biases.

Box 1. Key clinical takeaways and next steps for tactile stimulation research in DoC

1. Measure what matters (arousal vs. awareness)	Future studies should clearly distinguish outcomes indexing arousal (vigilance/reactivity) from those indexing awareness (purposeful, reproducible behaviors), prioritizing sensitive tools such as the CRS-R over the GCS when the aim is to detect changes in awareness.
2. Improve diagnostic specificity	Eligibility and reporting should clearly differentiate coma, VS/UWS, and MCS, and stratify analyses by diagnosis, given that the clinical meaning of arousal and awareness changes differs across conditions
3. Isolate the contribution of touch	Because tactile stimulation is often embedded in multimodal programs, studies should include matched control conditions (e.g., neutral touch/usual care) or factorial designs to better isolate tactile-specific effects.
4. Dose and timing are likely critical	Interventions should systematically report frequency, duration, intensity, and timing post-injury, and explicitly test dose – response effects and whether early (acute) stimulation yields larger or more durable benefits than later phases.
5. Leverage emotionally salient stimulation	Evidence suggests that family-delivered stimulation may enhance outcomes, potentially via familiarity/emotional salience; future trials should test this systematically (family vs. clinicians' delivery) with standardized training and fidelity checks.
6. Address sustainability of gains	Given that improvements may diminish when stimulation is withdrawn, protocols should incorporate long-term follow-up and investigate strategies to maintain gains (e.g., longer schedules, tapering, home/family continuation).
7. Methodological rigor	Given that improvements may diminish when stimulation is withdrawn, protocols should incorporate long-term follow-up and investigate strategies to maintain gains (e.g., longer schedules, tapering, home/family continuation).

Legend: DoC = Disorders of Consciousness; VS/UWS = Vegetative State/Unresponsive Wakefulness Syndrome; MCS = Minimally Conscious State; CRS-R = Coma Recovery Scale – Revised; GCS = Glasgow Coma Scale; RCTs = Randomized Controlled Trials.

Future research should aim to implement rigorous methodologies, including randomized controlled trials with larger samples, standardized diagnostic tools (e.g., CRS-R), and transparent reporting of stimulation characteristics. Moreover, future studies should explicitly separate outcomes indexing arousal (e.g., vigilance/reactivity) from those indexing awareness (e.g., CRS-R command-following, intentional communication, or reproducible purposeful behaviors), to better clarify which dimension of consciousness is most responsive to tactile stimulation. Furthermore, studies should explore the impact of tactile stimulation as a standalone intervention, as well as its potential synergistic role within multimodal rehabilitation. Long-term evaluations are also essential to determine the durability of treatment effects and to develop evidence-based guidelines for sustained stimulation in clinical practice. Key gaps and limitations in the current evidence-based and priorities for future research are synthesized in Box 1.

Conclusions

Even if the objective of this review was to understand the specific contribution of unimodal tactile stimulation compared to other sensory modalities (Figure 2 for a synthesis), the available evidence is limited, as most studies have investigated tactile stimulation as part of a broader multimodal approach. Consequently, the findings primarily reflect the effects of combined sensory stimulation rather than tactile

stimulation alone. Regarding the five guiding questions, tactile stimulation protocols were highly heterogeneous in terms of type (e.g., massage, brushing, grasping), targeted body areas (e.g., hands, feet, face), and methodology of delivery (e.g., passive vs. active stimulation). Frequency and duration also varied considerably across studies, ranging from single sessions to repeated daily administrations over several weeks. The most commonly used outcome measures were the GCS and CRS-R, although standardized behavioral tools were not always applied, and follow-up assessments were infrequent. Still, many studies reported short-term improvements in arousal and responsiveness, particularly when stimulation was early, frequent, and emotionally salient.

Overall, these studies collectively emphasize the importance of early, frequent, and multimodal sensory stimulation in improving consciousness and functional recovery, with tactile stimulation playing a relevant role. It seems essential to promote structured, long-term treatments with regular sessions of daily administration of tactile stimulation for individuals with DoC, to enhance recovery and maximize outcomes, ensuring that the positive effects are maintained and progressively built upon. Future studies should focus more explicitly on the isolated effects of tactile stimulation to better understand its unique impact on responsiveness and consciousness recovery in individuals with DoC and the possible long-term outcomes.

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Data availability statement

All data generated or analyzed during this study are included in this published article and its supplementary information files.

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