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Dyadic vs. triadic taxonomy of body representation: A scoping review of brain mapping studies

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ABSTRACT

Introduction: Body representation refers to how the brain processes information about the body, traditionally categorised by the dyadic taxonomy into body schema and body image. However, the triadic taxonomy proposes the inclusion of the body structural description and body semantics.
Objectives: This scoping review retrospectively mapped existing neuroimaging studies to the dimensions proposed by dyadic taxonomy and triadic taxonomy, aiming to identify neural activation patterns, conceptual alignments, and methodological challenges in the literature.
Methodology: Following Joanna Briggs Institute guidelines, studies published between 2005 and 2023 investigating body representation through neuroimaging in healthy adults were systematically searched across PubMed, EBSCO, and CENTRAL databases.
Results: Seven studies met the inclusion criteria. Findings indicated predominant activation of the parietal cortex, fusiform gyrus, and premotor cortex, with notable overlap between body schema and body structural description. No study explicitly adopted dyadic taxonomy or triadic taxonomy frameworks. Methodological heterogeneity, particularly variability in experimental paradigms and exclusive use of functional magnetic resonance imaging, limited comparability and temporal analysis of body representation processes.
Conclusion: Current neuroimaging evidence does not yet consolidate triadic taxonomy constructs, highlighting the need for theoretical standardisation and the integration of multimodal approaches to better delineate the neurobiological bases of body representation.

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INFORMAÇÃO DO ARTIGO

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RESUMO

Introdução: A representação corporal refere-se à forma como o cérebro processa informações sobre o corpo, sendo tradicionalmente categorizada pela taxonomia diádica em esquema corporal e imagem corporal. No entanto, a taxonomia triádica propõe a inclusão da descrição estrutural do corpo e da semântica corporal.

Objetivos: Esta scoping review realizou um mapeamento retrospetivo dos estudos de neuroimagem existentes segundo as dimensões propostas pela taxonomia diádica e taxonomia triádica, com o objetivo de identificar padrões de ativação neural, alinhamentos conceptuais e desafios metodológicos na literatura.

Metodologia: De acordo com as diretrizes do Joanna Briggs Institute, foram pesquisados sistematicamente estudos publicados entre 2005 e 2023 que investigassem a representação corporal através de técnicas de neuroimagem em adultos saudáveis, nas bases de dados PubMed, EBSCO e CENTRAL.

Resultados: Sete estudos cumpriram os critérios de inclusão. Os resultados indicaram uma ativação predominante do córtex parietal, do giro fusiforme e do córtex pré-motor, com uma sobreposição notável entre esquema corporal e descrição estrutural do corpo. Nenhum estudo adotou explicitamente os enquadramentos da taxonomia diádica ou da taxonomia triádica. A heterogeneidade metodológica, nomeadamente a variabilidade nos paradigmas experimentais e o uso exclusivo de imagem por ressonância magnética funcional, limitou a comparabilidade e a análise temporal dos processos de representação corporal.

Conclusões: A evidência atual proveniente da neuroimagem ainda não consolida os constructos da taxonomia triádica, salientando a necessidade de padronização teórica e da integração de abordagens multimodais para uma melhor delineação das bases neurobiológicas da representação corporal.

Introduction

Body representation (BR) refers to how the brain encodes, processes, and integrates information regarding one's own body, enabling the perception of its position, shape, and movement in space.[1] This concept is fundamental to neuroscience and human cognition, directly influencing interaction with the environment, motor execution, and subjective body experience.[2] Multiple neural systems contribute to BR by integrating sensory, motor, and cognitive signals.[3]

Traditionally, BR has been categorised according to the Dyadic Taxonomy (DT), distinguishing two main dimensions: the body schema (BS) and the body image (BI).[4] The BS is implicit and perceptual in nature, representing the body's spatial and biomechanical state, whereas the BI encompasses conscious, emotional, and conceptual aspects of the body.[1]

However, recent research indicates that DT may be insufficient to capture the full complexity of BR. Emerging studies propose a Triadic Taxonomy (TT), expanding DT by adding two additional components: the body structural description (BSD), a visuospatial map of the structural relationships between body parts; and body semantics (BSem), which relates to the functional and linguistic knowledge of body parts and their interactions with the environment.[5,6] Neuropsychological evidence, including brain mapping and lesion studies, support the dissociability of these dimensions.[7,8]

Disturbances in BR are often observed in neurological disorders and are a central focus in clinical practice, underlining the need for consistent theoretical models. Despite this relevance, the literature remains conceptually fragmented, with considerable variability in terminology. This lack of conceptual clarity complicates both empirical research and clinical assessment.[9] Neuroimaging techniques such as functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and magnetoencephalography (MEG) have facilitated investigations into the neural correlates of BR; however, conceptual inconsistencies still limit the synthesis of findings across studies.[9,10] A deeper neuroscientific understanding of BR could thus lead to more effective interventions for individuals with motor and perceptual dysfunctions and contribute to the development of more precise clinical assessment tools.

This scoping review does not assume that the TT is explicitly adopted in the existing literature. Instead, it retrospectively maps available evidence from neuroimaging studies onto the dimensions proposed by the TT, in order to explore whether such constructs are being implicitly addressed. The aim is to identify neuroimaging studies in healthy adults that examine any BR-related dimension aligned with DT or TT, characterise their conceptual frameworks and experimental paradigms, describe the implicated brain regions, and identify methodological and theoretical gaps that may inform future research.

Methodology

This scoping review was conducted following the Joanna Briggs Institute (JBI) recommendations to ensure transparency and reproducibility.[11] The study followed a structured process, including defining inclusion and exclusion criteria, formulating the search strategy, selecting studies, and extracting and synthesising data.

Inclusion and Exclusion Criteria

Studies were included if they investigated BR, regardless of the taxonomy used; employed brain mapping techniques such as fMRI, EEG, MEG, or similar methods; involved healthy adult participants; were published between 2005 and 2023, reflecting the introduction of TT in the literature in 2005;[12] were written in English, French, Spanish, or Portuguese, languages mastered by the reviewers; and were published in peer-reviewed scientific journals.

Studies were excluded if they exclusively involved clinical or paediatric populations; did not employ neuroimaging techniques; consisted of opinions, narrative reviews, conference abstracts, or book chapters; or did not provide direct experimental data on BR.

Search Strategy and Study Selection

The search was conducted across three electronic databases: PubMed, EBSCO (Elton B. Stephens Company), and CENTRAL (Cochrane Center Register of Controlled Trials). The search strategy combined controlled vocabulary and keywords: ("body schema" OR "body structural representation" OR "body semantics" OR "body image" OR "body representation" OR "body awareness" OR "body maps") AND ("cortical map" OR "cortical network" OR "brain area" OR "neural network" OR "cerebral map" OR "cerebral area" OR "connectome" OR "neuroimaging" OR "electroencephalography" OR "tractography" OR "functional magnetic resonance imaging" OR "magnetoencephalography" OR "positron emission tomography" OR "near infrared spectroscopy").

Identified studies were stored in the Zotero® reference manager, with duplicates removed automatically. Subsequently, five independent reviewers screened the titles and abstracts. Potentially eligible articles underwent a full-text review by the same five reviewers independently. Disagreements or uncertainties were resolved through consensus meetings involving two additional reviewers. Following these stages, articles fulfilling inclusion criteria were selected for data extraction.

Data Extraction and Synthesis

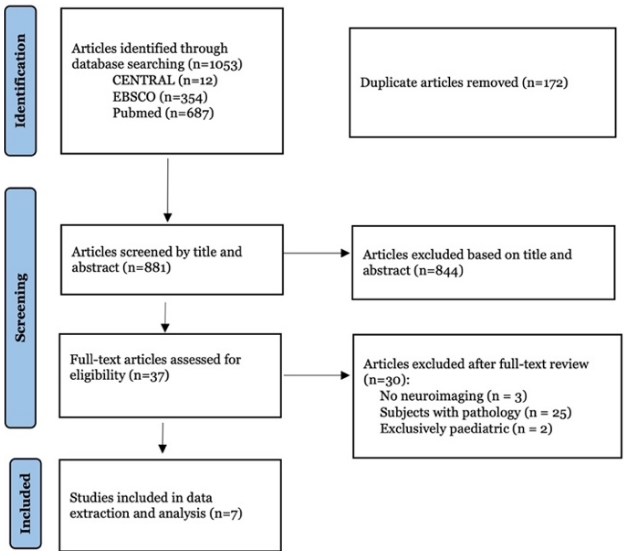

Figure 1. Flowchart of the article selection process

Data were extracted from selected studies according to the following categories: authors and publication year; country of origin; participants' age and sample size; experimental paradigms employed; type of body representation investigated (Body Schema, Body Image, Body StructuralDescription, or Body Semantics); taxonomy applied (DT or TT); brain mapping technique used; and key findings and conclusions.

To ensure reliability in data extraction, each article was analysed by three reviewers, with any disagreements resolved through consensus discussions involving two additional reviewers.

Ethical Considerations

Given that this literature review is based exclusively on previously published data, ethical approval was not required. Nevertheless, the study strictly adhered to principles of transparency, scientific integrity, and reproducibility.

Results

The search conducted on 3 December 2024 across PubMed, EBSCO, and CENTRAL databases yielded a total of 1,053 articles. After removing 172 duplicates, 881 articles remained for initial screening.

During the title and abstract screening phase, 837 articles were excluded for not meeting the inclusion criteria, leaving 37 articles for full-text review.

In the full-text review stage, 30 additional articles were excluded due to failure to meet the inclusion criteria. Consequently, 7 studies were selected for data extraction and analysis.[13–19] Figure 1 provides a flowchart illustrating the article selection process.

The selected studies address various dimensions of body representation and employ diverse brain mapping methodologies. Table 1 summarises the primary information extracted, including experimental methods, neuroimaging techniques used, main findings, and brain regions involved.

Table 1. Included studies

Author (Year)	Objective	Paradigm	Age	N	Taxonomy mentioned	BR type	Taxonomy	Brain mapping	Activated brain areas
Ehrsson et al. (2005)[13]	Identify neural correlates responsible for changes in body perception.	Shrinking-Waist Illusion	20-35 (24 ± 3.2)	24	No	BI	Dyadic	fMRI	Parietal cortex; ventral premotor cortex
McCrea et al. (2007)[14]	Investigate whether successful body representation tasks paired with verbal naming activate the left parietal lobe more than facial processing tasks.	Visual stimuli and naming of body parts	(27 ± 9)	9	No	BSem	Triadic	fMRI	Fusiform gyrus and extrastriate body area (EBA), left precuneus, right frontal lobe (precentral gyrus), right superior frontal gyrus, right cerebellum
Corradi-Dell'Acqua et al. (2009)[15]	Clarify neural mechanisms underlying body schema and body structural description.	Image observation	22-48 (28.31)	17	No	BS; BSD	Triadic	fMRI	BSD - left posterior intraparietal sulcus; BS - left secondary somatosensory cortex
Rusconi et al. (2014)[16]	Assess the structural body representation of fingers.	Intermanual interdigital task	(27 ± 4)	13	No	BSD	Triadic	fMRI	Left inferior parietal lobule; left inferior frontal gyrus; bilateral precuneus; bilateral premotor cortex; anteromedial inferior parietal lobe
Canderan et al. (2020)[17]	Investigate contrasts in processing body representations related to body positions.	Image analysis and body language	20-54 (31.3 ± 9.71)	20	No	BSD	Triadic	fMRI	Bilateral angular gyrus; middle anterior temporal gyrus; right superior temporal gyrus; inferior frontal gyrus; superior medial gyrus; left superior frontal gyrus; bilateral superior parietal lobule (7A); posterior-inferior temporal gyrus; middle frontal gyrus; left precentral gyrus
Matsumoto et al. (2020)[18]	Examine brain activity during the rubber foot illusion (RFI) and identify cerebral areas implicated in reconstructing the internal representation of the lower limb.	Rubber Foot Illusion	(21 ± 1.2)	48	No	BI	Dyadic	fMRI	Right RFI: bilateral medial and middle frontal gyri; left supplementary motor area; bilateral inferior parietal lobules; precuneus; calcarine cortex; cerebellar hemispheres; vermis; bilateral thalamus. Left RFI: bilateral medial, middle and superior frontal gyri; left inferior frontal gyrus; supplementary motor area; bilateral inferior parietal lobules; middle temporal gyri; left cerebellar hemisphere; vermis; bilateral thalamus. Joint analysis: prefrontal cortex; bilateral medial and middle frontal gyri; parietal cortex; bilateral inferior parietal lobules; cerebellum; bilateral cerebellar hemispheres; vermis.
Moayedi et al. (2021)[19]	Identify structural and functional mechanisms underlying changes in body image.	Visual body illusion	(24.3 ± 5.9)	18	No	BI	Dyadic	fMRI	Areas activated during illusion: bilateral occipito-temporal junction - extrastriate body area (EBA) and fusiform body area; bilateral posterior parietal cortex; bilateral lateral occipital cortex; left ventral premotor cortex

Abbreviations: BR = Body Representation; BI = Body Image; BS = Body Schema; BSD = Body Structural Description; BSem = Body Semantics; fMRI = Functional Magnetic Resonance Imaging; RFI = Rubber Foot Illusion; EBA = Extrastriate Body Area; N = Number of participants.

Discussion

The primary aim of this scoping review was to explore how brain mapping studies investigate BR, and to retrospectively assess the extent to which existing evidence aligns with the dimensions proposed by the TT. The findings reveal that, although some studies implicitly explored constructs compatible with TT, none explicitly adopted any formal taxonomy. This reinforces the ongoing conceptual and methodological heterogeneity in the field, complicating the comparability and generalisability of results.[9]

The analysis of brain regions implicated in BR showed considerable overlap between different dimensions, suggesting that traditional classifications (e.g., BS, BI, Body Structural Description) may not correspond to functionally distinct systems. This supports the idea that BR may be better understood as a continuum of interrelated processes rather than as strictly separate categories.

To facilitate the conceptual integration of the findings, Figure 2 provides a visual summary mapping the dimensions of the DT and the TT onto the main brain regions implicated in the reviewed studies. This representation highlights the considerable overlap between dimensions and underscores the need for a more integrated model of body representation.

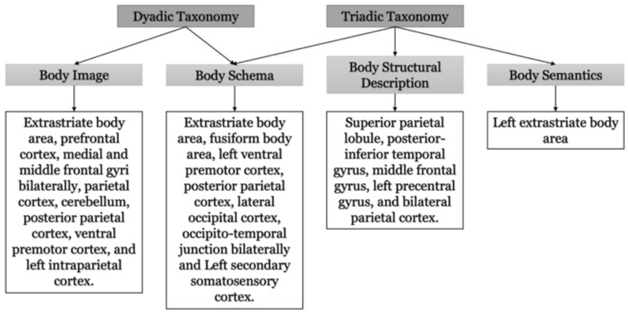

Figure 2. Conceptual mapping of body representation taxonomies and associated brain regions. **Legend:** The figure illustrates the main brain regions associated with the dimensions of the Dyadic Taxonomy— Body Schema and Body Image— and the Triadic Taxonomy— Body Schema (BS), Body Structural Description (BSD) and Body Semantics. Overlap of some regions between BS and BSD is noted.

The reviewed studies displayed distinct patterns yet identified shared brain regions across different BR dimensions. BI consistently activated regions such as the prefrontal cortex, medial and middle frontal gyri, parietal cortex, and cerebellum.[13,18,19] Activation of the prefrontal cortex likely reflects higher cognitive processing necessary for context-dependent evaluation and modification of BR. The cerebellum's involvement might relate to motor integration and predictive adjustments of posture and actions.[20]

In contrast, BS was associated with activations predominantly in the parietal cortex, particularly regions such as the superior parietal cortex and parietal lobules, known for visuomotor integration and motor control.[15,19] These findings align with existing literature emphasising the crucial role of these areas in visuomotor integration and postural control.[21] Nevertheless, findings suggest significant neural overlap between BS and Body Structural Description.

Body Structural Description involved bilateral activation in regions including the visuospatial processing areas of the superior and inferior parietal lobules, posterior temporal cortex, and middle frontal gyrus.[15–17] This bilateral pattern suggests involvement of both egocentric and allocentric processing, supporting theories of embodied cognition that emphasise dynamic interactions between self-perception and environmental context. [22,23]

Body Semantics was explicitly examined only in the study by McCrea (2007),[14] reporting activation in the extrastriate body area (EBA), potentially reflecting linguistic and functional body knowledge. However, further research is needed to clarify the empirical robustness and functional distinctiveness of this dimension.

One of the main challenges identified was the high variability in task paradigms. Some studies[13,18,19] employed perceptual illusions such as the Shrinking-Waist Illusion[13] and the Rubber Foot Illusion,[18] while others[14–17] utilised tasks with varying degrees of complexity. This methodological diversity hinders cross-study comparisons and the development of standardised taxonomic models.

Additionally, all included studies relied exclusively on fMRI, limiting insight into the temporal dynamics of BR processes. The absence of EEG or MEG techniques may reflect field preferences or resource availability, but their inclusion could offer valuable complementary data on the timing and sequence of neural activity. Future studies should consider multimodal neuroimaging approaches to capture both spatial and temporal aspects of BR.

Importantly, while this scoping review did not include formal quality appraisal—as per JBI methodology—a brief narrative assessment suggests that the selected studies generally used robust designs, with clearly defined tasks. Nonetheless, variability in sample size and analysis techniques across studies warrants cautious interpretation of patterns.

In sum, this review identified a consistent involvement of brain areas such as the parietal cortex, fusiform gyrus, and premotor cortex across various BR dimensions. However, the lack of taxonomic consensus and methodological inconsistencies suggest that BR remains a developing concept. Future research should adopt more unified theoretical models and standardised methods to better delineate BR constructs and their neural underpinnings.

Longitudinal studies are needed to understand how BR evolves over time and in the context of neurological injury or developmental conditions. Incorporating both clinical and non-clinical populations, as well as multimodal imaging, will be essential for translating neuroscientific evidence into effective interventions and accurate assessment tools.

This review has several limitations. First, the exclusion of grey literature (e.g., theses, dissertations, technical reports) may have introduced publication bias. Including such sources, as recommended by the JBI, could provide a more comprehensive view of the field. Second, the focus on healthy adults ensured neural homogeneity but limits generalisability to clinical populations. Finally, as a scoping review, no meta-analysis or formal quality evaluation was conducted.

Conclusion

The findings of this review highlight ongoing terminological and categorisation inconsistencies regarding BR in the literature. The TT has yet to be fully established as an alternative to the DT. Despite these challenges, advances in neuroimaging techniques and methodological refinements promise to enhance our understanding of the neuroscientific foundations of BR. Further research, adopting standardised methodologies and integrated paradigms, is crucial for clarifying the functional dynamics and dimensions of BR, ultimately enabling more precise clinical assessments and interventions.

Conflict of interest

No conflicts of interest were declared by the authors.

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