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Embodied experience in robot-assisted rehabilitation train-ing therapy: A bibliometric analysis (2014-2023)

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Abstract. Industry 4.0 technology has transformed human-robot interaction in robot-assisted rehabilitation therapy. However, most current studies focus on the patient's perceived "motor participation". Few studies have systematically reviewed the patient's experience, including their psychological involvement, perception, experience, and judgment of the rehabilitation environment, therapist, and robot, as well as examining the coupling of "mental participation" and "motor participation". This paper presents a systematic study and literature review from the perspective of the embodied experience of patients, utilizing a combination of the scoping review, performance analysis, science mapping, and bibliometrics analysis to examine relevant literature. The result emphasizes the significance and necessity of the patient's embodied experience in robot-assisted rehabilitation training therapy. Most research in this field is founded on embodied theory and embodied technology. This study provides an essential theoretical reference for the study of embodied experience in robot-assisted rehabilitation therapy, helping to improve theoretical and practical approaches to improve the users' embodied experience and aid user experience research and design in related research institutions and businesses.

Keywords: robot-assisted rehabilitation therapy, embodied experience, rehabilitation environment, user experience

1. Introduction

Rehabilitation robots are essential intelligent devices that replace important bodily functions during and after the rehabilitation process of patients and have enormous development potential in the rehabilitation and healing fields. In addition to assisting in the treatment of physiological dysfunctions 1], rehabilitation robots can also serve as intervention and treatment tools for psychological and behavioral disorders [2]. One of the most rapidly expanding research areas in robot-assisted rehabilitation training and treatment is complex interdisciplinary rehabilitation, in which medical, psychological, artificial intelligence, engineering, and design disciplines con-verge to enable the future development of rehabilitation robots that incorporate sensory feedback [3]. In the field of rehabilitation robotics, there

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are several mature technologies and theories, of which research hotspots focus on the research value and clinical application of the naturalness and robustness of rehabilitation robots, as well as the recognition of motor learning and brain plasticity and the integration of non-invasive neurostimulation, robot-assisted training, and virtual reality immersion. Associated with non-invasive neurostimulation, robot-assisted training, and virtual reality immersion, rehabilitation robots reduce patients' somatosensory, functional, and motor deficits. As such the repetitive, interactive, and intense training of the upper extremities of patients with mild paralysis can be aided more effectively by robot-assisted rehabilitation therapy [4].

Currently, the most existing research focuses on the active interaction between patients and rehabilitation robots, in which the robot perceives patients' real-time motor participation intentions and conducts training, accordingly, based on the perception of patients' "functional mobility" and ignoring patients' embodied experience. That refers to the patient's "mental participation," including the patient's perception, experience, evaluation of the rehabilitation environment, therapist, rehabilitation robot, and social participation [5]. In addition, the impact of embodied experience [6] refers to the patient's "mental participation" including the patient's perception, experience, evaluation of the rehabilitation environment, therapist, rehabilitation robot, and social participation. Since patients will perceive, experience, and evaluate the rehabilitation environment, therapists, and robots during rehabilitation training and treatment. Physical discomfort will lead to emotional disorders such as reduced self-identity [3]. In addition, while the satisfied rehabilitation functions, the patient's psychological experience should be clearly understood to achieve. As such it is important to make the rehabilitation product design in line with the patient's embodied experience.

Hence, this study seeks to analyze the research themes and produce in-depth insights that can inform future research directions in the field of patient-rehabilitation robot interaction based on patients' embodied experiences during robot-assisted rehabilitation training therapy. The paper further emphasizes the patient-specific experience in robotic rehabilitation, reveals the interaction between humans, robots, and the rehabilitation environment, and provides potential guidelines for maximizing patient outcomes and reducing disability.

2. Methods and Materials

A mixed research method adopted in this paper provides theoretical and methodological references for future research and assists in-depth understanding, which used bibliometric analysis to analyze current studies via performance analysis and science mapping. Performance analysis has been carried out on 1054 data retrieved from the Web of Science from which research areas have been visualized using CiteSpace. The method flow presented in Table 1, helps to examine the current state of research, collaborative networks, and research trends and to identify the scope of research from which insights can be gained into (1) research hotspots, frontier themes, and trends in the domain of robot-assisted rehabilitation training therapy; (2) embodied interaction between patients and rehabilitation robots in robot-assisted rehabilitation training therapy.

To pave the way for future theoretical and methodological research on embodied experience in robot-assisted rehabilitation training therapy, the practical approaches of affective computing, affective interaction, and embodied interaction are further analyzed.

Table 1. The Method Flow.

Title 1	Step1. Defining the research question
Scoping Review	Determine the scope of the study, investigate the present state of research and collaborative networks, and then formulate research questions.
	RQ1. Research hotspots, research edge, and trends in rehabilitation robotics. RQ2. embodied interaction between patients and rehabilitation robots in robot-assisted rehabilitation training therapy.

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Table 1. (continued).

<table>
<tr><td rowspan="7"></td><td colspan="3">Step2. Choosing the techniques for bibliometric analysis</td></tr>
<tr><td colspan="3">Core Database of Web of Science(SSCI、SCI、A&HCI)and bibliometric mapping software CiteSpace</td></tr>
<tr><td colspan="3">Step3. Searching,selecting and collecting the data</td></tr>
<tr><td rowspan="2">Search terms</td><td>Rehabilitation Robot related</td><td>(“rehabilitation*”AND “robot*”) AND</td></tr>
<tr><td>Embodied experience related</td><td>(“experience” OR “emotion*” OR “mind” OR “feeling” OR “behavior”)</td></tr>
<tr><td>Identification</td><td colspan="2">Review of literature titles and abstracts, screening out irrelevant literature by CiteSpace software and manually (PRISMA-ScR flow as literature inclusion and exclusion criteria)</td></tr>
<tr><td>Collection</td><td colspan="2">1054 included in quantitative analysis</td></tr>
<tr><td rowspan="5">Bibliometric Analysis</td><td colspan="3">Step4. Running the bibliometric analysis</td></tr>
<tr><td rowspan="2">Quantitative analysis</td><td>Performance analysis</td><td>Macro-quantitative analysis of search results in Web of Science core databases based on literature and co-citation data by histograms and graphs for time, author, research institution, country and journal</td></tr>
<tr><td>Science mapping</td><td>Analysis of current research hotspots, disciplinary structure and development trends through keyword co-occurrence mapping, keyword clustering mapping, timeline mapping and emergent word mapping, etc.</td></tr>
<tr><td rowspan="2">Qualitative Analysis</td><td colspan="2">The relationship between the rehabilitation robot and the patient’s experience of “psychological involvement” from an embodied experience perspective</td></tr>
<tr><td colspan="2">The application and importance of embodied experience in robot-assisted rehabilitation training therapy</td></tr>
<tr><td colspan="4">Step5. Discussion</td></tr>
<tr><td colspan="4">Step6. Conclusions</td></tr>
</table>

2.1. Data search, selection, and collection

Web of Science is one of the most widely used and peer-reviewed research databases across all disciplines, especially in the medical and health areas [7]. The search terms are (“rehabilitation*” AND “robot*”) AND (“experience” OR “emotion*” OR “mind” OR “feeling” OR “behavior”) AND (“experience” OR “emotion*” OR “mind” OR “feeling” OR “behavior”), from which Web of Science core collection with SSCI, SCI, and A&HCI indexed studies have been explored. Based on the PRISMA-SCR process, the titles, abstracts, authors, and keywords have been examined, of which duplicates, and irrelevant literature have been manually and automatically weeded out using CiteSpace software, producing 1054 papers in all for the data analysis.

2.2. Selection of analysis methods

The embodied experience of rehabilitation robots has been investigated using a mixed strategy that combined quantitative scoping review [8], science mapping, performance analysis and bibliographic analysis followed by a qualitative evaluation of the literature. In addition, the bibliometric network has been constructed and visualized in this study using CiteSpace software [9]. The analysis steps are as follows:

1. Macro quantitative -- performance analysis: macro-quantitative analysis of time, authors, research institutions, countries, and journals based on literature and co-citation data.
2. Quantitative science mapping: insight into current research hotspots, disciplinary structures, trends, and collaborative networks through keyword co-occurrence mapping, keyword clustering mapping, timeline mapping, and emergent word mapping.
3. Micro-qualitative analysis: analyzing the relationship between the rehabilitation robot, patient experience, and the environment from the perspective of embodied experience, clarifying the role and importance of the embodied experience of the treated person in robot-assisted rehabilitation training treatment, and analyzing the application fields and future development trends of embodied experience in robot-assisted rehabilitation training treatment.

3. Results

3.1. Macro Quantitative -- Performance Analysis

3.1.1. Publications and Citations. As shown in Figure 1, in year 2021, there were 132 pertinent publications, ap-proximately four times as many as in year 2013; the number of publications peaked in year 2021 and then declined slightly in year 2022 before rising steadily with an overall upward trend. The number of publications on related topics reflects the academic interest, and the higher number of publications, the more active the field's research. The rise of experience design encourages the academic community to consider problems from the user's perspective and to incorporate the user's embodied experience, emotion, perception, and co-experience into design practice [10]. The upward trend of research in this domain is expected to persist in the nearly future.

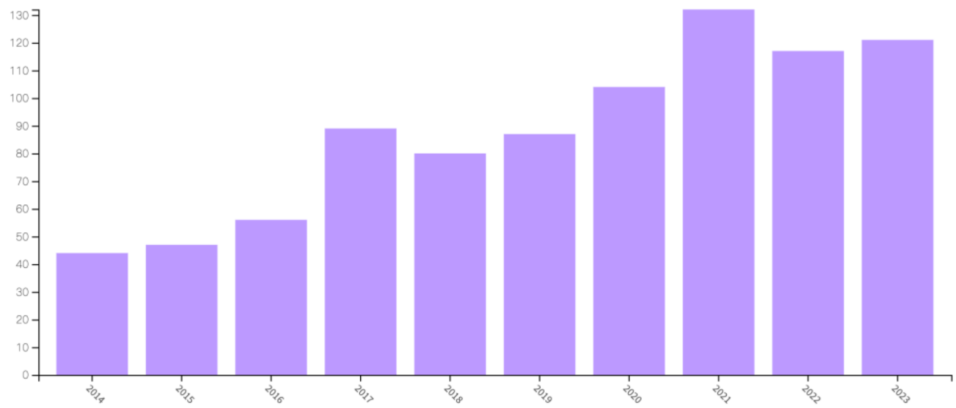

Figure 1. Publication from the years 2014 to 2023 via Web of Science.

3.1.2. Most Influential Publications. Table 2 shows the 5 most cited papers related to rehabilitation robots and patients' embodied experience in Web of Science. The top three significant papers are "Targeted Neurotechnology Restores Walking in Humans with Spinal Cord Injury ", "Wearable Haptic Systems for the Fingertip and the Hand: Taxonomy, Review, and Perspectives", and "Rehabilitation for Parkinson's Disease: Current Outlook and Future Challenges", all of which have been conducted from the patient's personal perspective, combined with the patient's personal experience and objective treatment results, to advance the field of rehabilitation medicine.

Table 2. The Top 5 Most-cited Papers.

No.	Author(s)	Year Published	Paper Title	Journal	Citation Count
1	Wagner,FB., et al.	2018	Targeted Neurotechnology Restore Walking in Humans with Spinal Cord Injury	Nature	519
2	Pacchierotti,C., et al.	2017	Wearable Haptic Systems for the Fingertip and the Hand: Taxonomy, Review, and Perspectives	IEEE Transactions on Haptics	357
3	Abbruzzese,G., et al.	2016	Rehabilitation for Parkinson's Disease: Current Outlook and Future Challenges	Parkinsonism & Related Disorders	225
4	Gallego,JA., et al.	2017	Neural Manifolds for the Control of Movement	Neuron	203
5	Giovacchini,F., et al.	2015	A Light-weight Active Orthosis for Hip Movement Assistance	Robotics and Autonomous Systems	182

3.1.3. Most Prolific Journals. The Web of Science database totally contains 361 reputable journals that focus on rehabilitation robotics and embodied experience. As shown in Table 3, 20.872% of the 1054 obtained papers originated from three the most prestigious journals: JOURNAL OF NEUROENGINEERING AND REHABILITATION (8.918%), IEEE TRANSACTIONS ON NEURAL SYSTEMS (8.444%), and SENSORS (3.510%), which followed by IEEE ROBOTICS AND AUTOMATION LETTERS, APPLIED SCIENCES BASEL, IEEE ACCESS, PLOS ONE, DISABILITY AND REHABILITATION, DISABILITY AND REHABILITATION ASSISTIVE TECHNOLOGY and FRONTIERS IN NEURO-ROBOTICS.

Table 3. The Top 5 Most Prolific Journals.

No.	Journal Title	Number of Papers	% of 1054
1	JOURNAL OF NEUROENGINEERING AND REHABILITATION	94	8.918
2	IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING	89	8.444
3	SENSORS	37	3.510
4	IEEE ROBOTICS AND AUTOMATION LETTERS	25	2.372
5	APPLIED SCIENCES BASEL	19	1.803

3.1.4. Most Prolific Research Interest. A total of 1054 papers were obtained from the Web of Science database, covering 106 different research fields. Table 4 show that the majority (73.435%) of the papers were derived from the top three research fields: Rehabilitation (27.894%), Engineering Biomedical

(24.478%), and Neurosciences (21.063%). These fields are all associated with rehabilitation robotics and the embodied experience of patients.

Table 4. The Top 5 Most Prolific Research Interests.

No.	Research Area	Number of Papers	% of 1054
1	Rehabilitation	294	27.894
2	Engineering Biomedical	258	24.478
3	Neurosciences	222	21.063
4	Robotics	154	14.611
5	Engineering Electrical Electronic	103	9.772

3.1.5. Most Prolific Authors. The Web of Science search data (as shown in Table 5) revealed that Riener, R.(16) and Courtine, G.(14) contributed the most studies on rehabilitation robots and patient embodied experience. Most field research primarily focuses on rehabilitation robotics technologies aimed at enhancing patient rehabilitation. Additionally, it explores whether patient engagement with robots during rehabilitation can alleviate pain and improve overall well-being.

Table 5 shows contributions to research in related fields, with the top5 most frequent authors are from various continents, of which a greater contribution is from Europe; including University of Zurich and EPFL in Switzerland, and Scuola Superiore Sant'Anna in Italy.

Table 5. The Top 5 Most Prolific Authors.

No.	Author	Affiliation	Country	Number of Documents	% of 1054
1	Riener, R.	University of Zurich	Switzerland	16	1.518
2	Courtine, G.	Ecole Polytechnique Federale de Lausanne (EPFL)	Switzerland	15	1.423
3	Hogan, H.	University of South Carolina Columbia	America	11	1.044
4	Micera, S.	Scuola Superiore Sant'Anna	Italy	11	1.044
5	Krebs, HI.	Massachusetts Institute of Technology (MIT)	America	8	0.759

3.2. Quantitative Science mapping

3.2.1. Keyword Co-occurrence Analysis and Cluster Analysis—Research Hotspots and Research Trends. Keywords are the words that the author refined to summarize the theme paper including high summary, refinement, and summary of the academic ideas, research themes, and research contents of a particular study. With each node representing a keyword and its size corresponding to the keyword's frequency, the Citespace software package creates a keyword co-occurrence map, which is used to analyze the 1054 obtained papers resulting in a keyword co-occurrence graph' as shown in Figure 2. "rehabilitation" and "therapy" are high-frequency keywords, and "experience", "movement", "behavior", "walking", "gait" and "performance" all emphasize the patient's embodied experience in the process of robot-assisted rehabilitation.

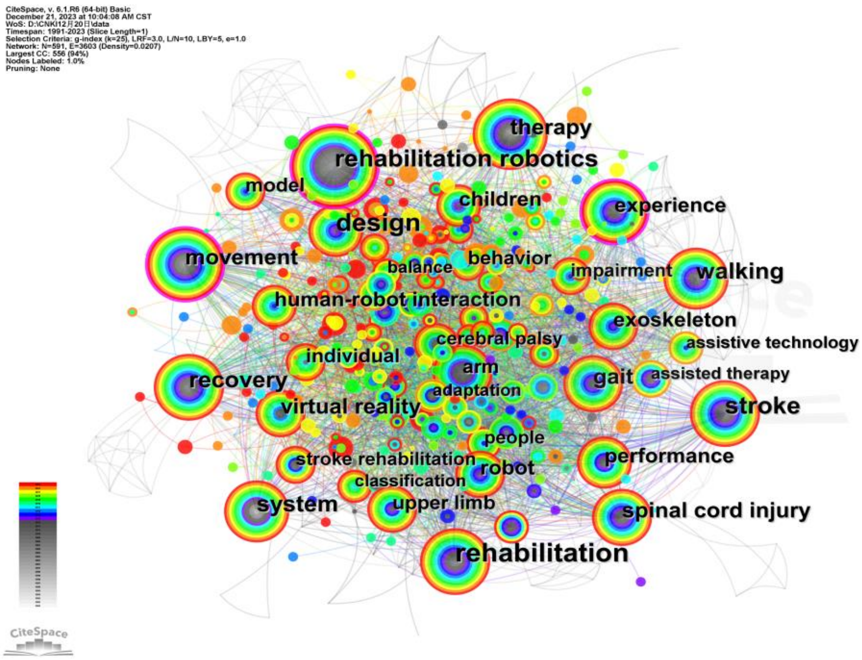

Figure 2. Keyword Co-occurrence Network for Embodied Experience in Robot-assisted Rehabilitation Training Therapy Literature.

In recent years, the impact of mental emotions on rehabilitation treatment has been a popular research topic. In the theory of embodied cognitive emotion, emotions are embodied, in a manifestation of bodily perceptions and responses that are mutually reinforcing with bodily responses, and the relationship between the mind and body [11]. I In robot-assisted rehabilitation training, patients will generate a series of perceptual experiences and cognitive activities, such as the perception of their surroundings, the experience of the treatment process, and the perception, analysis, and evaluation of robot-assisted treatment products [12]. On the road to recovery, unrelieved physical and mental pain and tension, as well as susceptibility to negative emotions such as anger and depression, can be a formidable obstacle.

As shown in Figure 3 a knowledge map of the clustering for the high-frequency keywords has been generated, with a Q value of 0.7211 (>0.3) suggesting that the obtained class cluster structure is significant, and a S value of 0.7878 (>0.7) indicating that the obtained clusters are effective and convincing. The clusters are designated according to their size, beginning with 0 for the largest cluster, and 1 for the second-largest cluster. As illustrated in Figure 6, the top 10 clusters formed by the high-frequency keywords are #0 brief review (cluster 0), #1 conventional therapy technique (cluster 1), #2 rehabilitation research (cluster 2), #3 innovative use (cluster 3), #4 motor learning (cluster 4),#5 single pellet (cluster 5), #6 rhythmic multijoint arm movement (cluster 6), #7 robust soft actuator (cluster 7), #8 soft computing technique (cluster 8) and #9 proprioceptive demand (cluster 9). Combining the clustering results with the most popular research topics, the keywords in the figure can be grouped into three main categories: “retrospective study”, “emerging technologies,” and “embodied experience.”

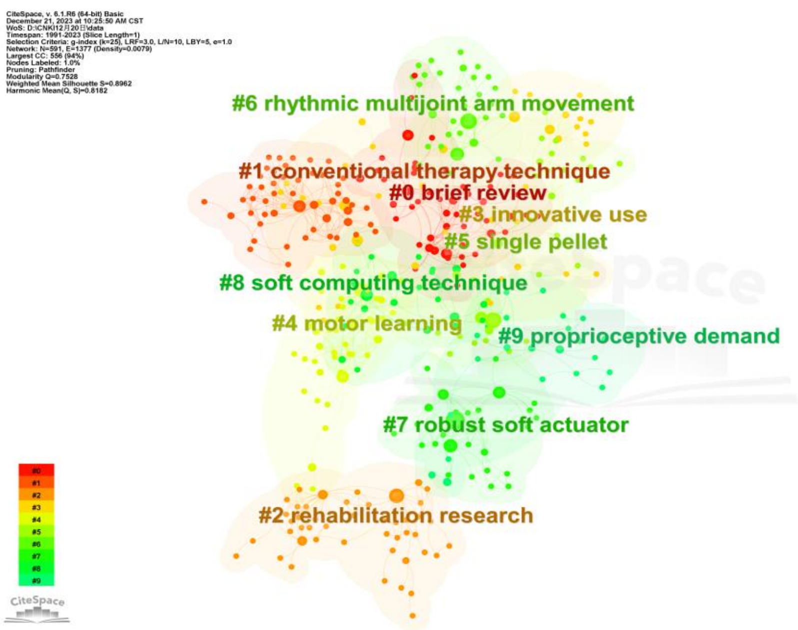

Figure 3. Keyword Co-occurrence Clustering Network for Embodied Experience in Robot-assisted Rehabilitation Training Therapy Literature.

The “retrospective study” includes #0 brief review, #1 conventional therapy technique, #2 rehabilitation research, and #5 single pellet. In addition to restricting the patient’s physical and motor abilities, impaired physical function also causes emotional and cognitive deficits and affects the patient’s family’s attitude [13]. After achieving a high level of physical recovery, many patients continue to suffer from psychological disorders. Furthermore, adverse emotional conditions such as stress, discomfort, boredom, and lack of motivation can have a detrimental effect on motor rehabilitation. Therefore, in the procedure of rehabilitation training robot-assisted patient rehabilitation, how to achieve natural and effective human-robot interaction, increase the comfort of the rehabilitation training process, alleviate the negative emotions of patients, and make the robot assist patients in rehabilitation training more effectively has become a hot topic.

“Emerging technologies” includes #3 innovative use, #7 robust soft actuator, and #8 soft computing technique, focusing on human-robot interaction. An example of a training strategy in human-robot collaborative gait rehabilitation involves adjusting the robot-assisted gait training reference trajectory according to the patient’s gait motion. In addition, the procedure of collaborative control of rehabilitation robot dependent on human-robot interaction consists of recognizing the patient’s movements and expressions, sensing the patient’s willingness to participate in real-time actively, and adjusting auxiliary training behavior accordingly while maintaining a high degree of consistency with the patient’s proactive participation [14]. Hence, the interactivity of collaborative control between patients and rehabilitation robots is an interesting research topic.

The term “embodied experience” is comprised of three clusters, namely #4 motor learning, #6 rhythmic multijoint arm movement, and #9 proprioceptive demand, which are under the umbrella of “embodied medicine,” that is the application of advanced technology to modify experiences of the body to enhance health outcomes [15]. The body plays a vital role in the rehabilitation process by encoding and integrating various multisensory signals, including somatosensory, visual, auditory, and motor signals. In addition, the body, and the embodied experience of the patient influence psychosocial and behavioral aspects. As such, taking into consideration the patient’s embodied experience in treatment design and incorporating emerging technologies to achieve naturalistic hu-man-computer interaction are emerging research topics in the field of enhancing patient psychological engagement.

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3.2.2. Keyword Mutation and Timeline Mapping Analysis--Research Frontiers and Trends. CiteSpace has been utilized to visualize the keyword emergence of the results, in which cutting-edge topics in the field have been analyzed in conjunction with related literature to predict future trends. As shown in Figure 4, "Strength" indicates the strength of the emergence, "Begin" and "End" are the beginning and end of the emergence, and the red line represents the beginning and end of the emergence. The red line represents the beginning and end of the emergence. The term with the longest mutation duration is "coordination" (lasting 13 years), followed by "body weight support" (lasting 12 years). As the mutation intensity is 6.2, "arm" is the most powerful word, followed by "task analysis" and "stimulation" with mutation in-tensities of 5.7 and 5.33, respectively. In recent years, the forefront of research has been in "intervention", "physical human-robot interaction", "legged locomotion", "task analysis" and "upper limb rehabilitation".

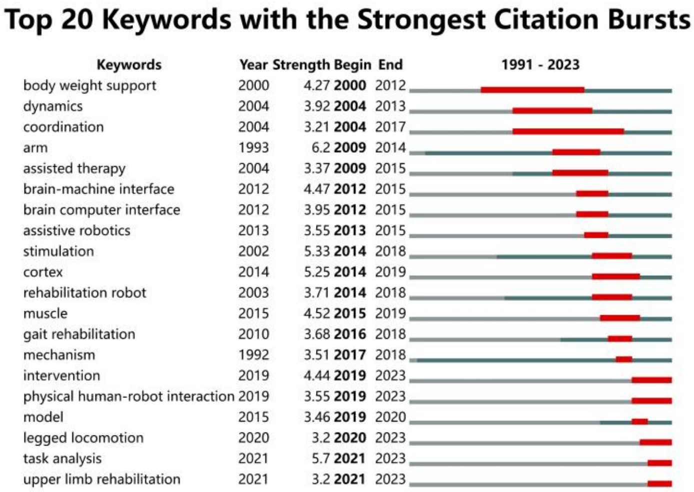

Figure 4. Mapping of Keyword Mutations in Embodied Experience in Robot-assisted Rehabilitation Training Therapy Literature.

Figure 5 shows the progression of keywords in the field of rehabilitation robot-assisted therapy design over ten years, as well as the evolutionary relationship between keywords in various time zones, revealed from which the following three issues can be identified:

First, the right end of the timeline in Figure 8 (near year 2023) presents "robot kinematics (#0 brief review)", "user experience (#1 conventional therapy technique)", "embodiment (#5 single pellet)", and "human-machine interaction (#8 soft computing technique)" illustrates the increasing emphasis on the embodied experience of patients in the research field. In the evaluation of treatment effectiveness, there has been a gradual shift from "motor participation" to a combination of "motor participation" and "mental participation" as the evaluation criteria.

Second, a synthesis of the findings in Section 3.2.1 reveals that the evolution of the research field has multiple strands, with strong multidisciplinary integration and transplantation. As such, the scope of the studies could be broadened and become more in-depth.

Third, the important keywords from left to right and from top to bottom of Figure 8 include "performance (#0 brief review)", "experience (#1 conventional therapy technique)", "quality of life (#4 motor learning)" and "behavior science (#9 proprioceptive demand)", which suggest that the research centers in the field are variable, continuous, and current and cutting-edge. Robot-assisted rehabilitation is adaptable and flexible, which allow patients to interact with their environment more readily, increase their social confidence and independence in daily life, and reduce their risk of depression during treatment [16].

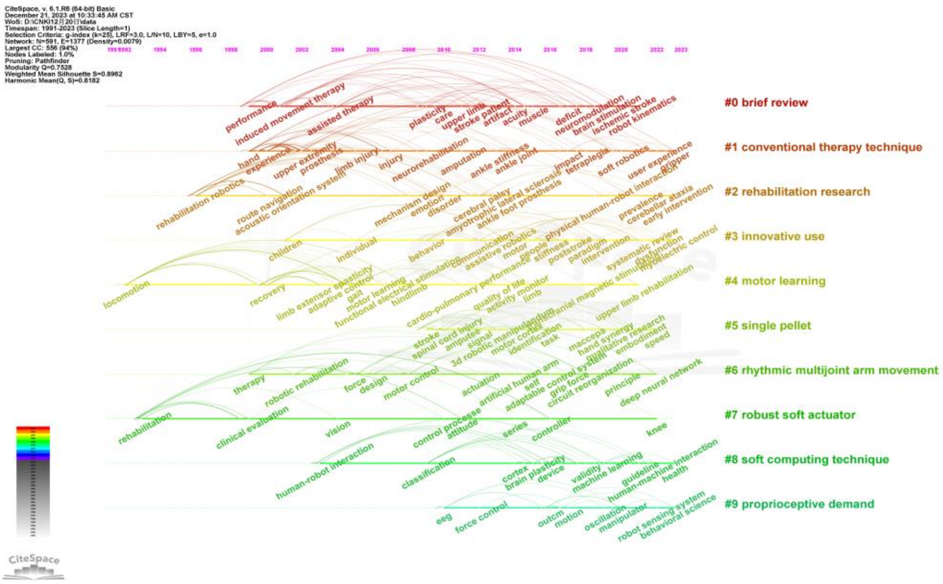

Figure 5. Timeline Mapping in Embodied Experience in Robot-Assisted Rehabilitation Training Therapy Literature.

4. Conclusion

4.1. Coupling of "mental participation" and "motor participation"

Through the above bibliometric study in Section 3.2 on the field of robot-assisted rehabilitation training and therapy, it has been determined that over the past decade, the research theme has gradually shifted from "passive participation" to "active participation" from the patient's perspective, and the criterion for the determination of the rehabilitation effect has gradually shifted from "motor participation" to a combination of "mental participation" and "motor participation" with an emphasis on the interdisciplinary nature of the field. In rehabilitation robot-assisted therapy, studies have investigated patients' emotions and mental activities, which have shown that certain physiological movement disorders are persistent and disabling, negatively impacting patients' anxiety, subjective well-being and perceptions of health-related quality of life.

However, a research gap exists in the coupling of "mental engagement" and "motor engagement", which is current robot-assisted rehabilitation therapy associated with both device technology and clinical aspects [17]. This paper revealed the importance of the "body" in the field, which attempts to conduct a macroscopic study of patients' emotions, mental activities, and aspects of embodied experience in robot-assisted rehabilitation training based on embodied cognition theory, with the goal of suggesting how to improve patients' "mental participation" and "motor participation" through robotic-assisted rehabilitation therapy.

During robot-assisted rehabilitation training, patients interact with the outside world through their bodies and sensorimotor systems, obtaining embodied experiences resulting in positive and long-lasting physiological or psychological changes in the individual. Throughout rehabilitation, monitoring and analyzing patients' embodied experiences such as experiences, emotions, perceptions, and behaviors through robot-assisted and technology-supported embodied learning and providing consistent feedback.

Therefore, this paper suggests the impact of simulations, contextual actions, and bodily states on the psychology and behavior of humans, for which the embodied approach assists researchers in comprehending the coupling and compatibility between "mental participation" and "motor participation" during robot-assisted rehabilitation.

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4.2. Embodied capabilities of rehabilitation robots

Robot-assisted rehabilitation therapy is capable of repetitive, interactive, and high-intensity training since the patient's embodied experience and embodied participation are conducive to rehabilitation therapy's efficacy. Based on the influence of the robot's affective cognition on changes in the emotional state of the interactant, affective computing can also enable rehabilitation robots to act on the "mental participation" aspects of the patient's body. It detects and evaluates the patient's physiological-psychological state, provides feedback on the depth of emotional changes, and provides emotional support to the patient throughout the interaction [19] by analyzing biosignals to monitor the physical state, determining the behavioral state through gait, gestures, and other body postures, and recognizing emotional states through facial expressions, voice, and gesture changes.

Affective computing technology can enhance the patient's initiative and focus during rehabilitation training, thereby facilitating the recovery of the patient's motor function. Embodied Mixed Reality Learning Environment (EMRELE) [20] and Virtual Reality (VR) integrate technologies of multimodal perception, modeling, and feedback to enable patients to interact with acoustic and visual media through whole-body motion in open space and receive feedback. The Kinect sensor-based development system [21] bridges the gap between concepts and real-world applications, improves the coupling of "mental-motor participation" and the embodied experience of the patient in the rehabilitation process, assists the patient in regaining the ability to exercise.

4.3. Embodied interaction in robot-assisted rehabilitation

Integrating human-robot interaction into rehabilitation training and treatment can significantly reduce the cost of rehabilitation training for patients while significantly enhancing the efficacy of rehabilitation treatment. Rehabilitation robots help to conduct an emotional assessment of the patient's non-verbal information and then establish embodied patient-robot interaction. During the process of playing nonverbal games with virtual reality systems, patients alleviate depression and anxiety related to diseases, reduce sensitivity, and fear in interpersonal relationships, and enhance cognitive abilities. Emotional interactive entertainment robots with rehabilitation effects can simulate patients' favorite faces, behaviors, and sounds to interact with them, and provide patient feedback based on their motivation, balance, emotions, and external sensor information.

Further, the embodied interaction between the robot and the patient enhances the induction, naturalness, and enjoyment of the treatment process, mostly repetitive functional or cognitive training, and helps the patient better integrate into the repetitive, interactive, and high-intensity rehabilitation training, to reduce the patient's resistance and negative emotions towards the rehabilitation treatment environment and increase their motivation to participate.

5. Conclusion

Increasing attention has been paid to the interactive experience in the rehabilitation environment and the embodied experience of patients, in which the "physio-psycho-social" medical model is playing a key role. This paper explores the hot spots, cutting-edge topics, and development trends in the field of robot-assisted rehabilitation therapy, analyzes correlation among robot, patient's embodied experience, and environment, and provokes the way of embodied experience in robotic rehabilitation therapy, in which the significance and application of the treated patient's embodied experience in the study of rehabilitation robots has been identified. In addition, this paper serves as a theoretical reference for studying embodied experience in robot-assisted rehabilitation therapy and contributes to improving theoretical and practical approaches to enhancing the user experience in robot-assisted rehabilitation therapy.

The theoretical contribution of this paper is to explore the field of robot-assisted rehabilitation therapy by combining quantitative and qualitative analysis, to reveal the significance and necessity of patients' embodied experience in robot-assisted rehabilitation therapy research, and to sort out the practical pathways of embodied experience in the field. In addition, this paper extends the original findings to explore bodily involvement including simulated, contextual actions and physical states, and embodied experiences influence patients' perceptions, experiences, cognition, and behaviors, as well as embodied interaction enhancing the therapeutic effects of robot-assisted rehabilitation therapy. Robot-assisted rehabilitation therapy should focus on the patient's embodied interaction, which is crucial to consider the patient's emotional feedback as a comprehensive rehabilitation factor. Further, research on the embodied interaction between rehabilitation robots and patients implies a focus on the coupling of "motor participation" and "mental participation" of patients, as well as on the embodied perceptual ability of rehabilitation robots.

Since, this paper employs analysis techniques such as scope review, knowledge map, and literature analysis. The scope of the sample selection is restricted to the Web of Science database, and the sample size is inadequate. The findings of this paper suggest that the influence of patients' embodied experiences on rehabilitation outcomes is an increasingly hot subject for future research in the field, for which its mode of action and practical application require a further study. These findings could facilitate implications for the study of natural and effective human-machine interactions among patients and rehabilitation robots and rehabilitation environments, which suggest future directions for studies to explore patients' "functional deficits" and emotional disorders, and to use emerging technologies across disciplines to capture, identify, process, and provide feedback on patients' physical and emotional states.

Data Availability Statement

Publicly available datasets were analyzed in this study. These data can be found here: https://login.webofknowledge.com/ (accessed on 30 December 2023).

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