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A scoping review of somatosensory interaction design for mental health and well-being

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ABSTRACT

This study explores the efficacy of somatosensory interactions in enhancing mental health care by examining the deployment and impact of these technologies. Based on a scoping review of 46 research studies, our analysis reveals that traditional mental health interventions often fail to align with prevalent technological trends. However, somatosensory interactions bridge this gap by creating immersive and engaging experiences. Our findings show considerable variability in the effectiveness, user engagement levels, and application methods of somatosensory technologies. Certain technology designs are particularly effective in promoting emotional well-being and reducing stress. Nonetheless, the diverse outcomes among the studies highlight the influence of factors such as design quality and user demographics. This variability underscores the need for more targeted studies to refine the application of somatosensory technologies, ensuring their effectiveness across different population segments. Ultimately, our insights emphasise the need to develop robust guidelines for integrating these technologies into comprehensive mental health strategies, thereby enhancing the related overall outcomes.

1. Introduction

Mental health has become a significant area of concern, paralleling the emphasis traditionally placed on physical health. The global rise in mental health problems across various demographic sectors highlights a pressing need for effective therapeutic strategies that integrate seamlessly into modern lifestyles, which are increasingly mediated by technology (OECD & World Health Organization, 2022). Yet, traditional mental health interventions often struggle to fully engage people, as they may not align with the digital habits that dominate their everyday lives. To fill the gap, somatosensory interactions involve the use of technology to simulate touch and other sensory experiences and the integration of this technology into virtual environments to enhance how individuals interact with the digital world. This creates an immersive and engaging experience, bridging the gap between digital and physical realities. To name a few examples:

- Tactile feedback systems use haptic feedback to simulate the sensation of touch. Devices such as gloves, vests, and handheld controllers equipped with actuators provide realistic touch sensations. These tactile systems can mimic the feel of a comforting human touch, which has been shown to reduce stress and anxiety (Smith et al., 2022).
- Vibrotactile devices use vibrations to deliver sensory stimuli and are often integrated into wearable products such as wristbands or patches. Vibrotactile stimulation has been used to regulate physiological responses, such as heart rate and breathing, to promote relaxation and reduce symptoms of anxiety and depression (Brelet & Gaffary, 2022). The rhythmic vibrations can also be synchronised with therapeutic music or guided meditation sessions to enhance their calming effects (McDaniel & Panchanathan, 2020).
- Thermal feedback systems involve the use of temperature changes to simulate environmental conditions or emotional states. For example, a device might cool down to evoke a sense of calm or warm up to provide comfort. These systems have been shown to be particularly effective in creating immersive virtual environments where temperature variations can enhance the realism and emotional impact of the experience (Günther et al., 2024).
- Force feedback and resistance devices provide resistance or force against the user's movements and are often used in physical therapy

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and rehabilitation settings. In mental health applications, force feedback can be used to simulate relaxing or meditative activities, such as the sensation of floating in water or the resistance of a gentle breeze. Such interactions can help individuals feel more grounded and provide a sense of physical presence and stability (Haynes et al., 2022).
- Multisensory integration systems that combine tactile, vibrotactile, thermal, and force feedback can be used to create highly immersive and interactive experiences. These integrated systems are designed to engage multiple senses simultaneously, creating a holistic therapeutic environment. Research indicates that multisensory interactions can significantly enhance user engagement and the overall effectiveness of mental health interventions (Brelet & Gaffary, 2022).

The diversity of somatosensory interaction designs reflects the innovative approaches being explored to enhance mental health and well-being. However, the varying levels of user engagement and effectiveness underscore the need for further research to identify the most effective designs and applications. This review highlights the potential of somatosensory technologies to provide personalised, non-invasive, and engaging therapeutic options, ultimately aiming to improve mental health outcomes across various populations.

In recent years, there has been an increasing interest in the potential of somatosensory interactions in the field of mental health, where tailored sensory stimulation can be strategically deployed to evoke therapeutic responses or to promote relaxation and reduce stress (Brelet & Gaffary, 2022; Kasai et al., 2020). For example, tactile and sensory feedback can simulate the comforting sensation of human touch or recreate calming environments, which are both known to have therapeutic effects (Haynes et al., 2022). This capability is invaluable in mental health care, as it offers a non-invasive, self-managed form of therapy that can be seamlessly integrated into daily life without the stigma typically associated with traditional mental health treatments. Nevertheless, to date, there has been no systematic review of studies related to somatosensory interactions for mental health and well-being.

To fully harness the potential of somatosensory technologies in mental health care, it is crucial to ground their applications in established theoretical frameworks. These frameworks highlight the mechanisms by which tactile, vibrotactile, thermal, and multisensory feedback can enhance mental health outcomes. First, the theory of embodied cognition underscores the profound connection between the body and mind, suggesting that cognitive and emotional processes are deeply rooted in physical interactions with the environment. Somatosensory technologies, such as haptic feedback systems, leverage this principle by engaging users in embodied experiences that influence their psychological states. For instance, devices that simulate comforting physical sensations, such as a gentle touch or the resistance of force-feedback systems, can foster emotional regulation and provide a sense of grounding during stressful moments (Smith et al., 2022). These embodied interactions create a bridge between physical sensations and mental well-being, offering a unique avenue for therapeutic engagement.

Second, stress reduction and relaxation theories further illustrate the value of somatosensory technologies in alleviating mental health challenges. These theories emphasise the role of relaxation in reducing stress and promoting psychological balance. Vibrotactile feedback devices, for example, synchronise with breathing exercises or therapeutic music to regulate autonomic responses such as heart rate and respiration. Similarly, thermal feedback systems that deliver warming or cooling sensations can simulate calming environmental conditions, contributing to reduced physiological arousal and a heightened state of relaxation (Haynes et al., 2022). These sensory interventions offer a non-invasive and engaging approach to managing stress, making them particularly suitable for individuals seeking alternative or supplementary therapeutic methods.

Third, biofeedback and self-regulation theories highlight the ability of individuals to monitor and control physiological states when provided with real-time feedback. Somatosensory devices equipped with haptic or vibrotactile feedback enable users to gain awareness of bodily signals such as muscle tension or heart rate variability. For example, a vibrotactile wearable that delivers alerts during periods of heightened stress allows users to respond proactively by engaging in self-regulation techniques such as deep breathing or progressive muscle relaxation (Béquet et al., 2022). By fostering a sense of agency, these technologies empower individuals to take an active role in managing their mental health.

Fourth, the principles of cognitive-behavioural therapy (CBT) also align well with the application of somatosensory technologies. CBT focuses on modifying maladaptive thoughts and behaviours through structured interventions. The integration of tactile feedback and sensory reinforcement can enhance CBT techniques by providing a tangible, immediate component to therapy. For instance, vibrotactile feedback during exposure therapy can simulate calming sensations that counteract fear responses, while haptic reinforcement might reward positive behavioural changes. These sensory elements augment the cognitive and verbal strategies central to CBT, making interventions more engaging and accessible (McDaniel & Panchanathan, 2020).

Finally, neuroplasticity and multisensory integration emphasise the brain's ability to adapt and reorganise in response to sensory input. Somatosensory technologies that combine tactile, auditory, and visual feedback engage multiple neural pathways simultaneously, creating immersive therapeutic experiences. This multisensory engagement enhances emotional regulation, strengthens neural connectivity, and maximises user engagement. For example, combining vibrotactile feedback with guided relaxation exercises or calming visuals creates a comprehensive sensory environment that facilitates psychological recovery and well-being (Villena-Gonzalez, 2023). These examples underscore the growing diversity and innovative applications of somatosensory technologies in mental health care, yet they also highlight the need for a systematic analysis to understand their full potential and limitations.

Against the above background, this scoping review synthesises published research on the application and design of somatosensory interactions for mental health and well-being. It examines the diversity of application methods and the varying levels of user engagement fostered by these technologies, reflecting the complex nature of this emerging field. The review analysed 46 papers published between 2019 and 2024, addressing the following questions:

- What types of somatosensory interactions are used to maintain and treat mental health and well-being?
- What gaps exist in the current body of research regarding the effectiveness of somatosensory interactions for promoting mental well-being?
- What are the implications of the current body of research for the design and application of somatosensory interactions in mental health interventions and treatments?

The selection of 2019 as the starting point for this review is underpinned by recent significant advancements in somatosensory interaction technology and its applications in mental health. A bibliometric analysis highlighted a marked increase in the number of relevant studies beginning in 2019, coinciding with key technological advancements in wearable devices, haptic feedback systems, and augmented/virtual reality technologies (Smith et al., 2022; Li et al., 2024). These innovations have significantly improved the accessibility, usability, and scalability of somatosensory interventions, facilitating their integration into mental health care practices. Additionally, this period witnessed a surge in interdisciplinary research driven by growing global awareness of mental health challenges and the urgent need for innovative, non-invasive therapeutic solutions (World Health Organization, 2022). The convergence of technological progress and heightened societal focus on mental health marked a pivotal shift, as researchers began to incorporate multisensory and digital approaches into traditional therapeutic frameworks. This review, therefore, focuses on studies published in or after 2019 to capture these transformative developments and provide a contemporary synthesis of this rapidly evolving field.

2. Materials and methods

2.1. Search strategy

We defined the focus of this review by limiting it to technology-based studies on somatosensory interaction design and mental well-being. The keywords used included *somatosensory, mental health, well-being, augmented reality, force feedback, haptic feedback, immersive technology, multisensory integration, non-invasive therapy, relaxation, sensory feedback, somatosensory technology, stress reduction, tactile system, thermal feedback, therapeutic interaction, touch stimulation, vibrotactile stimulation, virtual reality, and wearable haptic device*. We searched the Web of Science digital library, Google Scholar, and Scopus databases in 2024 using the following terms and connectors for the query: TI = (somatosensory OR 'mental health' OR well-being OR 'augmented reality' OR 'force feedback' OR 'haptic feedback' OR 'immersive technology' OR 'multisensory integration' OR 'non-invasive therapy' OR relaxation OR 'sensory feedback' OR 'somatosensory technology' OR 'stress reduction' OR 'tactile system' OR 'thermal feedback' OR 'therapeutic interaction' OR 'touch stimulation' OR 'vibrotactile stimulation' OR 'virtual reality' OR 'wearable haptic device').

2.2. Selection criteria

We restricted our search to articles within the following research fields: arts and humanities, computer science, design, engineering, psychology, science and technology, and social sciences. We limited our search to journal articles, articles in press, book chapters, and conference papers written in English and published in or after 2019, which marks the emergence of relevant research. The same search strategy was then applied to six other databases (Google, ACM, IEEE, Springer, Scopus, and Taylor & Francis), with minor adjustments made according to the specific search requirements of each database. We did not impose any discipline restrictions on the ACM and IEEE digital libraries as they are already focused on computer science publications.

To narrow down our search, we began by removing any duplicate entries retrieved from multiple databases. We then conducted an initial screening of titles and abstracts to exclude articles that were clearly irrelevant to our focus on somatosensory interaction design and its impact on mental well-being. We also removed articles that offered redundant information without new insights. Articles were selected based on their relevance to our research themes, specifically those discussing technological designs aimed at enhancing emotional well-being, reducing stress, or facilitating somatosensory interaction. Each article was then assessed for methodological rigour and relevance, prioritising studies with robust experimental designs, significant sample sizes, and clear outcomes related to our research focus. Finally, we conducted a full-text review for articles that passed the initial screening and met the inclusion criteria to ensure they provided substantial insights into somatosensory interaction design and mental well-being.

Our search criteria retrieved a total of 46 articles (see Fig. 1). This approach ensured a comprehensive review of the most relevant and interdisciplinary studies pertaining to our focus on somatosensory interaction design and its impact on mental well-being. The included studies exhibited diverse methodologies, with most using quantitative designs focused on measurable outcomes, while a smaller subset utilised qualitative approaches to explore participants' experiences. This methodological diversity reflects the exploratory nature of the field but also introduces challenges in terms of comparability and generalisability. By integrating these diverse findings, this review aims to synthesise both numerical data and experiential insights to provide a comprehensive overview.

3. Results

3.1. Research design

As indicated in Fig. 2, the majority of the 46 studies (58.70 %) used a quantitative research design. This reflects a strong preference for empirical and measurable data, which are valuable for producing statistically significant results. However, the dominance of quantitative research may also suggest an over-reliance on numerical data, potentially neglecting the deeper, contextual insights that qualitative research can provide. In contrast, only 26.09 % of the studies used qualitative methods. This underrepresentation of qualitative methodology may lead to a lack of rich and detailed participant experiences and perspectives, which are crucial for a holistic understanding of the research topics. A mixed-methods approach, combining both qualitative and quantitative techniques, was adopted by 13.04 % of the studies. While this approach can offer a more comprehensive understanding by integrating numerical data with narrative insights, the relatively low number of such studies indicates that more integrated methodologies could be used in future studies. Furthermore, only 2.17 % of the studies were proof-of-concept, highlighting a limited focus on exploratory research. Exploratory studies are essential for pioneering new ideas and technologies, and their scarcity might limit the field's potential for innovation.

For instance, Hu (2023) conducted a randomised controlled trial on somatosensory interactive games for autistic children, exemplifying the quantitative research trend. However, although this approach provides robust empirical data, it may not capture the full spectrum of participant experiences and contextual factors. In contrast, Li et al. (2024) utilised focus group discussions in their qualitative research on somatosensory games for hand function training in autistic children, offering rich, detailed insights that might be missed using quantitative methods. On the other hand, Yu et al (2020) conducted a mixed-methods study to evaluate a somatosensory square dance system for older adults, effectively balancing the strengths of both quantitative and qualitative research.

These examples highlight the need for a more balanced research methodology that incorporates qualitative insights alongside quantitative data. Such an approach can provide a fuller, more nuanced understanding of the impacts and effectiveness of somatosensory interactive technologies, ultimately leading to more informed and comprehensive conclusions. By integrating both empirical and contextual data, future research can better address the complexities and varied experiences associated with these technologies, thereby fostering innovation and improving user outcomes.

3.2. Population

Fig. 3 illustrates the distribution of age groups involved in the 46 studies. Adults represent the largest segment, comprising 53 % of the

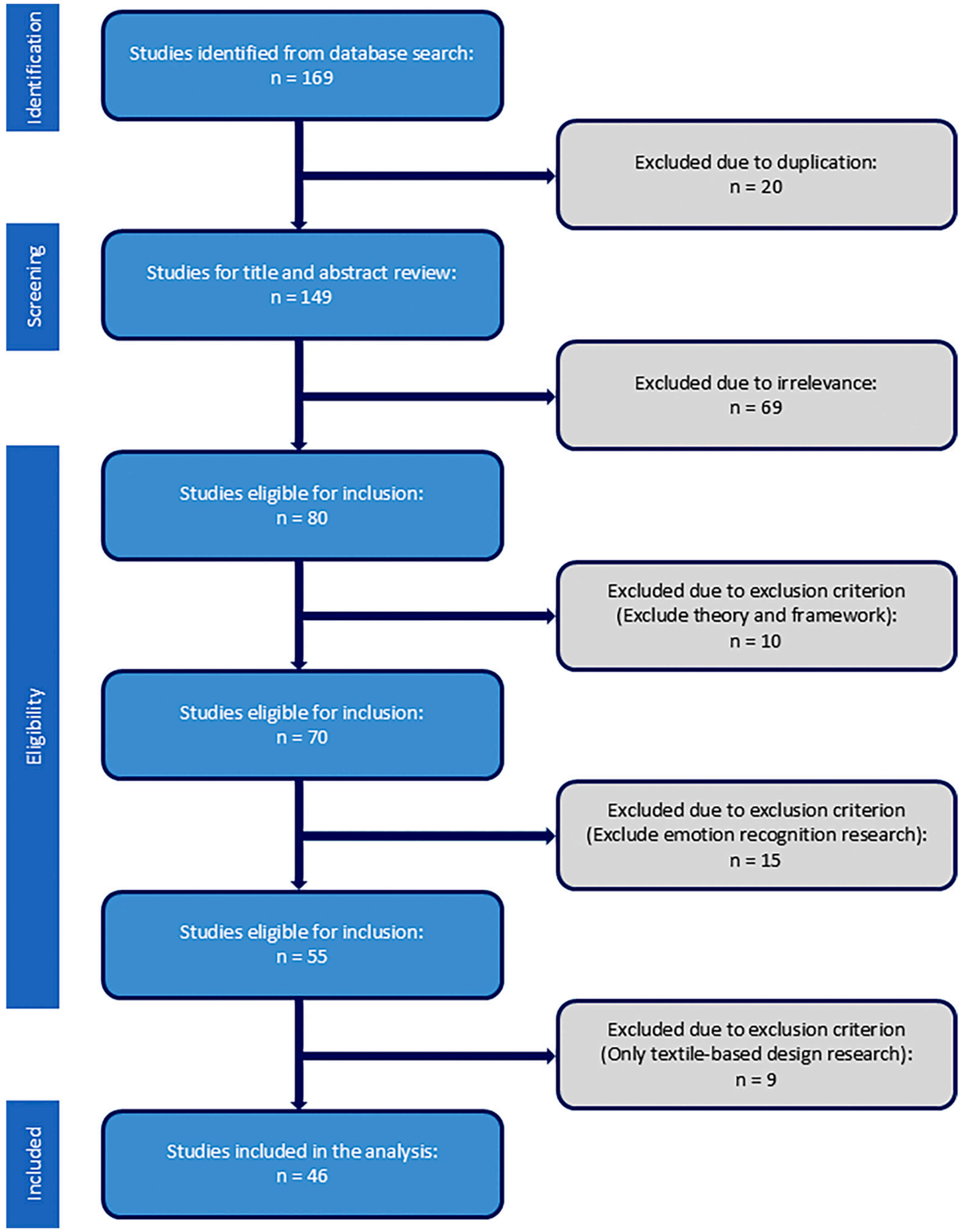

Fig. 1. Flow diagram of the inclusion and exclusion process of the studies.

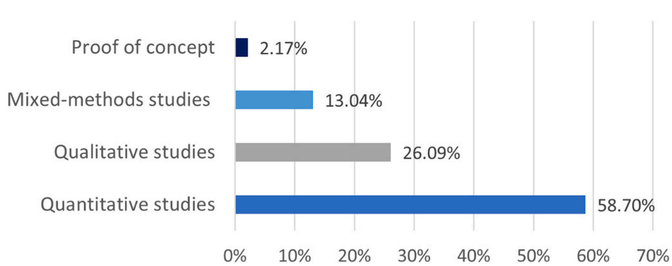

Fig. 2. Distribution of age groups involved in the 46 studies.

studied population. This significant majority indicates a predominant focus on the adult demographic in somatosensory interaction design research. The focus on adults may stem from the ease of recruiting adult participants and the immediate applicability of findings to this broad and economically active group. The second largest segment is older adults, making up 20 % of the population. This suggests an increasing recognition of the importance of addressing the mental health and well-being of older adults, particularly considering the aging global population and the specific challenges they face, such as isolation and declining physical health.

Youth and young adults represent 17 % of the studied population, suggesting a moderate level of attention. While this group receives considerable attention, there remains a need for more targeted research, particularly addressing mental health issues specific to this developmental stage, such as stress, anxiety, and social pressure. Indeed, the mental health and well-being of children and young people who have been or are currently in care is a priority in health and social care (Eapen et al., 2023). These individuals experience higher levels of mental health problems than the general population and are more than three times as likely to attempt suicide (Rodway et al., 2023). It is thus essential to prioritise mental health and well-being support for care-experienced

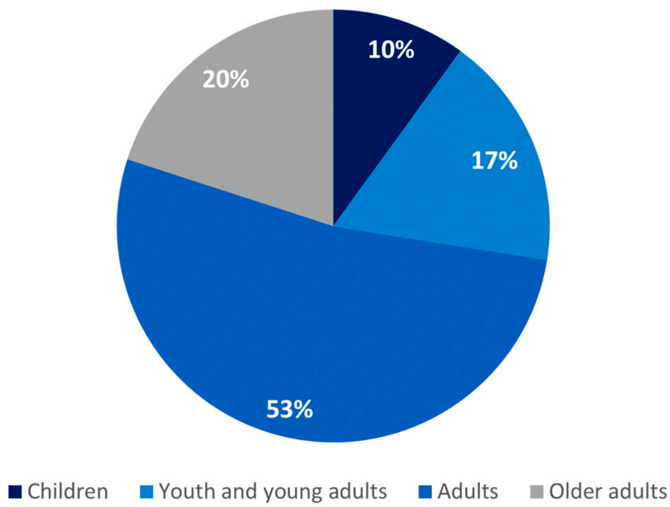

Fig. 3. Research design types.

children and young people. Given the increasing rates of mental health issues in younger populations, more emphasis should be placed on designing somatosensory interventions that cater to their unique needs. Children constitute the smallest segment at 10 %, indicating a significant underrepresentation in the research. This gap highlights a critical area that requires more attention, as early intervention can have profound long-term benefits on mental health. Research on somatosensory interaction designs for children could provide valuable insights into how to effectively support their mental and emotional development.

The current trend shows a substantial focus on adult and older adult populations, probably due to the immediate and visible impacts on these groups. However, the underrepresentation of children and, to some extent, youth and young adults suggests a clear and pressing need to broaden the scope of research. Future studies should aim to balance this distribution by increasing the focus on younger populations, ensuring that the mental health and well-being interventions developed are inclusive and cater to the needs of all age groups.

3.3. Mental health issues addressed in the studies

A thematic analysis of the 46 studies on somatosensory interaction design for mental health and well-being was conducted to provide a comprehensive overview of the diverse range of mental health challenges they addressed (see Table 1). The studies span various age groups, populations, and specific mental health issues, reflecting the multifaceted nature of mental health and the tailored interventions required to address them effectively (see Tables 2–7).

3.3.1. Theme 1: Usability and well-being in older adults

This cluster encompasses a broad spectrum of topics, including usability and well-being in older adults, rehabilitation, inter-generational interaction, creativity, anxiety and emotional well-being, somatic symptom distress, emotional well-being through housework, learning and communication, emotional semantics, communication for language barriers, loneliness in the elderly, tangible interaction, touch-rich interactions, and panic disorder in children. This diversity highlights the wide-ranging impact of somatosensory interaction design in improving mental health and well-being across different demographics and conditions.

Studies in this cluster, such as Yu et al. (2020) and Chang et al. (2023), underscore the importance of accessibility and usability in the design of interventions aimed at older adults. These studies suggest that when interventions are user-friendly and consider the specific needs of older populations, they can significantly enhance well-being and promote active engagement. However, a critical gap in this cluster is the

Table 1
Thematic analysis of mental health issues.

Theme	Focus	Representative Studies
Theme 1: Usability and well-being in older adults	Usability and well-being in older adults, rehabilitation, inter-generational interaction, creativity, anxiety and emotional well-being, somatic symptom distress, emotional well-being through housework, learning and communication, emotional semantics, communication for language barriers, loneliness in the elderly, tangible interaction, touch-rich interactions, panic disorder in children.	Ma and Li (2019), Woodward et al. (2019), Jacobs (2020), Yu et al. (2020), DaudéN Roquet and Sas (2021), Li and Gan (2021), Lim (2021), Wang et al. (2021), Zhu et al. (2021), Chasqueira et al. (2022), Hennemann et al. (2022), Yang et al. (2022), Yaseen and Timoney (2022), Chang et al. (2023), Deusdado and Antunes (2023), Holt (2023), Lu and Liao (2023), Shenoy and Kumar (2023), She Y.Y. et al., 2023, Slovak et al. (2023), Peng et al. (2024).
Theme 2: Autism spectrum disorder and physical training	Autism spectrum disorder, muscle strength training in older adults, balance training, mental well-being in children, hand function training.	Woodward et al. (2020), Haynes et al. (2022), Wagener et al. (2022), Zhang et al. (2022), Hu (2023), She H.L. et al. (2023), Li et al. (2024).
Theme 3: General mental health and technological interventions	General mental health improvement, meditation and attention regulation, astronauts' mental health, music therapy, virtual reality for mental illness treatment.	Kim et al. (2019), McDaniel and Panchanathan (2020), Brelet and Gaffary (2022). Claisse et al. (2022), Eapen et al. (2023), Rodway et al. (2023), Villena-Gonzalez (2023).
Theme 4: Happiness, well-being, and social interaction	Happiness and well-being, social interaction, hedonic well-being, eudaimonic well-being, stress regulation.	Meijer et al. (2021), Barrios-O'Neill and Pakalkaitė (2022), Gallace and Girondini (2022), Matheus et al. (2022), Günther et al. (2024). Som et al. (2024).
Theme 5: Anxiety, emotional well-being, and autonomous sensory meridian response	Anxiety and emotional well-being, autonomous sensory meridian response and emotional regulation, itch reduction, general mental health improvement, emotion regulation interventions.	Woodward et al. (2019), Kasai et al. (2020), Barcelos et al. (2021), Barrios-O'Neill and Pakalkaitė (2022), Béquet et al. (2022), Brelet and Gaffary (2022), DaudéN Roquet et al. (2022), Smith et al. (2022), Coulter (2023), Villena-Gonzalez (2023).

Table 2
Interactive games and exergames.

Study	Type of Somatosensory Interaction
Yu et al. (2020)	Somatosensory square dance system.
Zhu et al. (2021)	Inter-generational interaction through square dance activities.
Zhang et al. (2022)	Interactive exergame incorporating Tai Chi exercises for balance training.
Hu (2023)	Motion-sensing games developed with Unity3D and Kinect SDK.
She H.L. et al. (2023)	Somatosensory interactive games and traditional picture book activities.
Li et al. (2024)	Somatosensory games development focused on hand function and self-care training.
Som et al. (2024)	Somatosensory games enhance physical activity, cognitive function, and social interaction in older adults.

Table 3
Haptic feedback technologies.

Study	Type of Somatosensory Interaction
Meijer et al. (2021)	Affective and non-affective touch.
Béquet et al. (2022)	Haptic biofeedback of heart rate.
Brelet and Gaffary (2022)	Haptic feedback simulates touch to enhance VR-based stress reduction.
Günther et al. (2024)	Haptic feedback technologies simulate touch using pressure, temperature, and body position cues.
Haynes et al. (2022)	Haptic technology simulating slow breathing.
Matheus et al. (2022)	Haptic interactions and audio cues.
Wagener et al. (2022)	Passive haptic feedback (artificial grass) and auditory feedback (footstep sounds) at feet level.
Coulter (2023)	Augmented touch through e-textiles designed to embody natural environments and emotions.
Shenoy and Kumar (2023)	Tactile feedback through a ring that interacts physically with the user.

Table 4
Augmented reality and virtual reality.

Study	Type of Somatosensory Interaction
Kim et al. (2019)	Visuo-haptic-based multimodal feedback in a VR setting.
Kasai et al. (2020)	VR's tactile, visual, and auditory interactions for pain relief.
Li and Gan (2021)	VR-based somatosensory interaction.
Brelet and Gaffary (2022)	Haptic feedback enhances touch experiences in AR and VR for stress reduction.
Deusdado and Antunes (2023)	Haptic vest in VR environment.
Holt (2023)	VR, AR, mixed reality technologies providing visual, auditory, and haptic feedback.
She Y.Y. et al. (2023)	VR-based auditory and visual stimuli, tactile (e.g., soft blankets to simulate velvet petals).
Peng et al. (2024)	Use of a VR system providing multi-modal ASMR triggers including visual, auditory, and tactile (vibrotactile feedback) channels.

Table 5
Tangible interfaces.

Study	Type of Somatosensory Interaction
Woodward et al. (2019)	Tangible interfaces for mental well-being and their challenges.
Woodward et al. (2020)	Tangible toys with embedded sensors and feedback actuators, using Bluetooth for peer-to-peer support and feedback communication.
DaudéN Roquet and Sas (2021)	An interactive tangible device leveraging interoceptive interaction with thermal feedback to enhance internal bodily awareness during meditation.
Lim (2021)	Utilisation of familiar objects embedded with technology for intuitive interaction and emotional connection (e.g., pillows, walls, headphones that react to user input such as touch and presence).
Claisse et al. (2022)	Shape-changing materials, haptics, e-textiles, etc.
Haynes et al. (2022)	Tangible interfaces like teddys, balls, and cushions embedded with sensors.

long-term effectiveness of these interventions. Although immediate benefits are evident, there is a need for longitudinal studies to assess sustained impacts over time. Additionally, while the diversity of topics is a strength, it also presents a challenge in terms of integrating findings across different focal areas to develop a cohesive understanding of best practices in somatosensory interaction design for older adults.

3.3.2. *Theme 2: Autism spectrum disorder and physical training*

This cluster centres on autism spectrum disorder (ASD), muscle strength training in older adults, balance training, mental well-being in children, and hand function training. Studies in this cluster, such as those by She et al. (2023) and Li et al. (2024), highlight the potential of somatosensory interventions to support the developmental and social needs of children with ASD. These interventions can improve concentration, physical coordination, and interpersonal relationships, which are crucial areas of development for the children. However, a critical analysis reveals that although these interventions show promise, there is a lack of standardisation in the design and implementation of these somatosensory games and activities. The studies use varied methodologies, making it challenging to compare their results and draw general conclusions. Future research should aim to establish standard protocols and guidelines to ensure consistency and reproducibility. Moreover, the scalability of these interventions in real-world educational and clinical settings remains an open question, necessitating further investigation into their practical application and long-term benefits.

Table 6
Augmented and affective touch.

Study	Type of Somatosensory Interaction
Meijer et al. (2021)	Affective and non-affective touch.
Villena-Gonzalez (2023)	Affective touch and ASMR triggers (whispers, personal attention, caressing).

Table 7
Other technologies.

Study	Type of Somatosensory Interaction
Ma and Li (2019)	Gesture recognition technology.
McDaniel and Panchanathan (2020)	Games, toys, play, emotion regulation, stimulation therapy, distributed touch therapy, haptics for social wellness.
Woodward et al. (2020)	AI-assisted art creation.
Barcelos et al. (2021)	Tactile interactions with dogs.
DaudéN Roquet et al. (2022)	Thermal feedback via on-body heat actuators.
Wang et al. (2021)	Somatosensory hat with brain wave detection sensors and LEDs.
Barrios-O'Neill and Pakalkaitė (2022)	Design of touch-rich interfaces that provide more tactile feedback.
Chasqueira et al. (2022)	Use of a portable, cube-shaped interactive device (Kub-E) that guides children through tasks using CBT principles to manage panic attacks.
Hennemann et al. (2022)	Internet-delivered cognitive behavioural therapy.
Gallace and Girondini (2022)	Haptic devices in VR environments.
Smith et al. (2022)	Tactile interaction, using vibrotactile feedback with frequency modulation to enhance pressure perception in prosthetic and teleoperated devices.
Yang et al. (2022)	Smart blanket with pressure and temperature feedback via IoT.
Yaseen and Timoney (2022)	IoT devices and smart musical instruments.
Chang et al. (2023)	Smart somatosensory wearable assistive device.
Eapen et al. (2023)	Digital tools, telehealth, AI, and wearables as key technologies for improving youth mental health care.
Lu and Liao (2023)	3D point cloud, AI recognition for intelligent navigation and object interaction, modular hardware and software, somatosensory interaction.
Rodway et al. (2023)	Psychological impacts of online visual and auditory content on youth.

3.3.3. *Theme 3: General mental health and technological interventions*

This cluster focuses on general mental health improvement, meditation and attention regulation, astronauts' mental health, music therapy, and virtual reality (VR) for mental illness treatment. It represents a burgeoning area of research in which advanced technologies such as VR, artificial intelligence (AI), and haptic feedback are being harnessed to create innovative mental health interventions. Studies such as those by Haynes et al. (2022) and McDaniel and Panchanathan (2020) demonstrate the potential of these technologies to provide immersive and engaging therapeutic experiences. However, the reliance on technology also introduces challenges related to accessibility and user adoption. For instance, VR and AI technologies can be cost-prohibitive and require technical literacy, potentially limiting their reach to more technologically adept populations. Moreover, there is a critical need for robust clinical trials to validate the efficacy of these technologically driven interventions. Although initial results are promising, rigorous scientific validation is necessary to establish these technologies as reliable components of mental health care.

3.3.4. Theme 4: Happiness, well-being, and social interaction

This cluster emphasises happiness and well-being, social interaction, hedonic well-being, eudaimonic well-being, and stress regulation. Studies in this cluster, such as those by Matheus et al. (2022) and Som et al. (2024), illustrate how somatosensory interventions can enhance social interaction and overall happiness, particularly among elderly populations. These findings are important as they highlight the role of community and physical engagement in mental well-being. However, a deeper analysis reveals that many of these studies focus on short-term outcomes, with limited exploration of their long-term sustainability and effectiveness. The social and psychological benefits of interventions such as somatosensory games and tactile interactions with animals are evident, but it remains unclear how these benefits evolve over time. Future research should incorporate longitudinal designs to track the sustained impact of these interventions. Additionally, there is a need to explore the relevance and adaptability of these interventions across social and cultural contexts.

3.3.5. Theme 5: Anxiety, emotional well-being, and autonomous sensory meridian response

This cluster focuses on anxiety and emotional well-being, autonomous sensory meridian response (ASMR) and emotional regulation, itch reduction, general mental health improvement, and emotion regulation interventions. Studies such as those by Coulter (2023) and Villena-Gonzalez (2023) highlight innovative approaches to managing anxiety and enhancing emotional regulation using technologies such as augmented touch and ASMR. Although these studies contribute valuable insights, there is a critical need to address individual variability in response to such interventions. Anxiety and emotional well-being are highly subjective experiences, and what is effective for one individual may not be for another. This calls for personalised approaches to somatosensory interaction design, with careful consideration of individual preferences and needs. Furthermore, the ethical implications of using such intimate technologies for mental health interventions need to be thoroughly examined to ensure they are used responsibly and with informed consent.

To conclude, a notable trend in the reviewed studies is the increasing use of advanced technologies such as VR, AI, and haptic feedback to address various mental health challenges. These technologies offer new avenues for personalised and engaging interventions, making mental health support more accessible and effective. However, the rapid pace of technological advancement poses its own set of challenges. There is a pressing need for interdisciplinary collaboration between technologists, psychologists, and healthcare providers to ensure that these interventions are not only technically feasible but also psychologically effective and ethically sound. Overall, the thematic analysis highlights the potential of somatosensory interaction design to revolutionise mental health interventions. However, there are significant gaps, particularly in the representation of children and younger populations, as well as a need for more studies focusing on the long-term impacts and scalability of these interventions. Future research should aim to balance the focus across different age groups and mental health issues, ensuring that interventions are inclusive and comprehensive. Additionally, there is a need for more rigorous evaluation methods to establish the efficacy and sustainability of these innovative approaches in real-world settings. The promise of these technologies is immense, but their true potential will only be realised through careful, sustained, and ethical research and implementation.

3.4. Types of somatosensory interaction

The thematic analysis of the types of somatosensory interactions utilised in the reviewed studies reveals a wide array of methods and technologies. These interventions span multiple modalities, including haptic feedback, VR, tangible interfaces, and interactive games, each targeting specific aspects of mental health and well-being. This section critically examines the predominant types identified within the studies, highlighting their strengths, limitations, and areas requiring further research.

3.4.1. Interactive games and exergames

These constitute a significant portion of the reviewed interventions, focusing primarily on enhancing cognitive, physical, and social functions, particularly in children with autism and older adult populations. For instance, She H.L. et al. (2023) utilised somatosensory interactive games and traditional picture book activities to improve concentration and physical coordination in autistic children. Similarly, Zhang et al. (2022) developed an interactive exergame incorporating Tai Chi exercises for balance training in elderly individuals. These interventions demonstrated notable short-term benefits, such as improved motor skills and increased social interaction. However, the long-term efficacy of these games remains underexplored. Integrating these games into routine therapeutic practices poses substantial challenges, including the need for sustained engagement and the risk of technological obsolescence. Additionally, the high cost and complexity of developing and maintaining these interactive systems may limit their accessibility, particularly in under-resourced settings. Future research must develop robust frameworks to standardise the implementation and evaluation of these interventions, ensuring they are both effective and sustainable.

3.4.2. Haptic feedback technologies

Such technologies are extensively used to simulate physical sensations, facilitating emotional regulation and anxiety reduction. For example, Haynes et al. (2022) developed a haptic technology simulating slow breathing to alleviate anxiety, while Béquet et al. (2022) explored haptic heart rate biofeedback for stress regulation. These technologies offer promising avenues for personalised mental health interventions, yet their effectiveness can vary significantly among individuals. Customising these solutions to accommodate personal preferences and physiological responses is critical. Moreover, the high cost and technical complexity of haptic devices may impede their widespread adoption. There is also the challenge of ensuring these devices are user-friendly for diverse populations. Future research should focus on developing affordable, scalable, and user-friendly haptic technologies that can be easily integrated into existing mental health frameworks.

3.4.3. Augmented reality and virtual reality

Augmented reality (AR) and virtual reality (VR) technologies provide immersive environments for therapeutic interventions, enhancing user engagement and efficacy. Deusdado and Antunes (2023) used a haptic vest in a VR environment to treat mental illness, whereas Peng et al. (2024) utilised multi-modal ASMR triggers in VR to enhance mental well-being. Despite their potential, the accessibility and user-friendliness of AR and VR technologies remain significant barriers. The complexity of these systems can be daunting for users, particularly older adults or those with limited technological literacy. Furthermore, the high costs associated with AR and VR equipment may restrict access to these interventions. To realise their full potential and ensure they are accessible to a broader audience, future research should focus on simplifying these technologies and making them more cost-effective.

3.4.4. Tangible interfaces

Tangible interfaces are designed to provide physical interaction points that support mental health interventions. Woodward et al. (2020) developed tangible toys with embedded sensors for improving children's mental well-being, while DaudéN Roquet and Sas (2021) used an interactive tangible device to support mental health among youth. These interfaces offer intuitive and engaging ways to deliver therapeutic interventions. However, the development and maintenance of tangible interfaces are resource-intensive, and their therapeutic effectiveness requires further empirical validation. Ensuring the safety and durability of these devices, particularly for vulnerable populations such as children, is paramount. Moreover, the cost and complexity of producing these interfaces may limit their widespread adoption. Future research should aim to create more affordable and robust tangible interfaces that can be seamlessly integrated into therapeutic practices.

3.4.5. Augmented and affective touch

These technologies aim to enhance emotional experiences through tactile feedback and touch-based interactions. Villena-Gonzalez (2023) explored the use of affective touch and ASMR triggers, such as whispers and caresses, for emotional regulation. Similarly, Meijer et al. (2021) examined the use of affective and non-affective touch for reducing itch experiences and enhancing pleasantness. Although these studies underscore the potential of touch-based interventions in providing comfort and emotional support, the subjective nature of touch and individual differences in tactile sensitivity pose significant challenges. Standardising these interventions across diverse populations is difficult, and their effectiveness can be highly variable. Future research should focus on developing personalised touch-based therapies that cater to individual needs and preferences, ensuring they are both effective and broadly applicable.

3.4.6. Other technologies

Several studies have explored novel technologies and their applications in mental health interventions. Chang et al. (2023) developed a smart somatosensory wearable assistive device for home rehabilitation, while Yaseen and Timoney (2022) discussed Internet of Things (IoT) devices and smart musical instruments for ubiquitous musical interactions. These innovative approaches demonstrate the versatility of somatosensory technologies. However, implementing these advanced technologies requires substantial investment in infrastructure and training. The rapid pace of technological advancement also poses a risk of obsolescence, necessitating continuous updates and adaptations to keep pace with new developments. Additionally, the ethical implications of using such technologies, particularly concerns about data privacy and user consent, need to be thoroughly examined.

3.4.7. Studies exploring broader interaction frameworks

Two studies, Jacobs (2020) and Slovak et al. (2023), explored somatosensory interaction through broader theoretical and conceptual frameworks, without specifying a particular interaction type. These studies offer valuable perspectives that highlight the need for practical applications to further understand their implications. Future research could build on these foundations by developing actionable interventions and conducting empirical evaluations to assess their effectiveness.

3.5. Thematic analysis

The thematic analysis of the findings from the 46 studies on somatosensory interaction design for mental health and well-being provides a detailed examination of primary and secondary outcomes, assessment methods, and main findings. This section critically evaluates the insights and challenges presented by the studies, highlighting the diverse applications and varying effectiveness of different somatosensory interventions.

A significant number of studies focused on enhancing mental and physical well-being through somatosensory interventions. For example, She et al. (2023) reported that somatosensory interactive games significantly improved concentration, special abilities, and physical coordination in autistic children, while traditional picture book activities enhanced interpersonal relationships and language skills. This study highlights the importance of tailored interventions that consider individual differences in symptoms and abilities, suggesting that a combination of interactive and traditional methods may be most effective. Similarly, Yu et al. (2020) demonstrated the usability of and participant satisfaction with a somatosensory square dance system for older adults, noting improvements in indoor exercise routines, family relationships, and relaxation. Som et al. (2024) demonstrated that somatosensory games increased social interaction among elderly residents and maintained their willingness to exercise, significantly improving happiness indicators related to health, autonomy, and social aspects. These findings highlight the potential of somatosensory interventions to enhance both physical and mental health in elderly populations, particularly within structured care environments like nursing homes.

The acceptance and usability of technology are critical to the success of somatosensory interventions. Chang et al. (2023) reported the good usability performance of a smart somatosensory wearable assistive device for home rehabilitation during the pandemic, with higher acceptance among females with previous rehabilitation experience. This underscores the importance of considering demographic differences in technology adoption. Similarly, Coulter (2023) found a positive reception towards e-textiles designed to embody natural environments and emotions, promoting emotional self-regulation and stress management among students. These studies highlight the necessity of user-friendly designs and the potential for integrating natural elements into mental health interventions.

Several studies focused on emotional regulation and anxiety reduction through haptic and VR technologies. Haynes et al. (2022) demonstrated that a tactile aid simulating slow breathing was as effective as guided meditation in reducing anxiety, emphasising the therapeutic potential of haptic technology. Shenoy and Kumar (2023) reported that a wearable device with tactile feedback effectively monitored and regulated anxiety symptoms, providing real-time interventions. These findings underscore the need for advanced sensor capabilities and VR in future developments to enhance emotional regulation.

Villena-Gonzalez (2023) proposed a theoretical framework linking ASMR and affective touch, suggesting that their biological basis benefits emotional and psychophysiological regulation. Although the study was theoretical, it provides a foundation for future empirical research to explore the neurobiological links and therapeutic potential of ASMR and affective touch.

Studies have also explored the impact of somatosensory technologies on social interaction and loneliness. Zhu et al. (2021) demonstrated that sensory design interventions in public spaces can facilitate positive inter-generational interactions, enhancing community well-being and reducing ageism. Yang et al. (2022) proposed a smart blanket with pressure and temperature feedback to reduce loneliness among the elderly, integrating video communication with tactile interaction. These findings highlight the potential of somatosensory interventions to foster social connections and address loneliness, particularly among older adults.

Several interventions aimed to improve cognitive and physical functions. Zhang et al. (2022) found significant improvements in gait speed, balance, and mobility through an interactive Tai Chi-based exergame, although the improvements in cognitive function were not significant. This suggests that further studies are needed to confirm the cognitive benefits and ensure the broad applicability of these interventions. Hu (2023) reported that a motion-sensing game effectively promoted muscle strength and balance among older adults, highlighting the importance of gamification in encouraging physical activity.

Although the reviewed studies highlight the potential benefits of somatosensory interactions, several challenges remain. These are summarised as follows:

- Variability in effectiveness: Individual differences in responses to interventions necessitate personalised approaches. For instance, the

effectiveness of haptic feedback varies widely among individuals, requiring customisable solutions.
- Cost and accessibility: The high costs and technical complexities of devices such as VR systems and haptic technologies limit their accessibility. Future research should focus on developing cost-effective, scalable solutions.
- Long-term efficacy: Many of the studies demonstrated short-term benefits, but the long-term efficacy and sustainability of these interventions remain underexplored. Longitudinal studies are needed to assess lasting impacts.
- Integration into routine practice: Implementing these technologies into routine therapeutic practice poses significant challenges. Robust frameworks for the standardisation and evaluation of interventions are essential to ensure their effective integration.

The thematic analysis of somatosensory interaction types and research findings revealed a broad spectrum of innovative approaches aimed at enhancing mental health and well-being. These technologies offer promising new avenues for intervention, but face challenges related to accessibility, individual variability, long-term efficacy, and integration into routine practices. Future research should aim to develop more personalised, cost-effective, and user-friendly somatosensory technologies, ensuring their broad applicability and effectiveness in diverse populations. The true potential of these interventions will only be realised through sustained, ethical research and careful implementation, providing comprehensive mental health support across an array of contexts and communities.

The reviewed studies encompass a rich diversity of approaches and methodologies, yet the evidence varies significantly in terms of robustness and depth. Quantitative studies, which comprise the majority (58.7 %), provide statistically significant results, enhancing their generalisability. However, the reliance on numerical data often overlooks nuanced participant experiences and contextual factors, as highlighted by qualitative studies. For example, Hu (2023) focused on empirical measures such as muscle strength improvements yet omitted detailed accounts of user satisfaction and adaptability to the intervention. In contrast, qualitative studies (26.09 %), such as Li et al. (2024), offer in-depth insights into user experiences but lack the statistical generalisability necessary for scaling up interventions. This methodological imbalance highlights the need for mixed-methods approaches, which represented only 13.04 % of the studies reviewed. Mixed-methods studies, such as Yu et al. (2020), demonstrate the value of integrating quantitative efficacy measures with qualitative narratives to provide a holistic understanding of somatosensory interactions. Additionally, the limited representation of exploratory proof-of-concept studies (2.17 %) suggests that the field is underdeveloped in terms of pioneering new concepts and technologies, which are critical for innovation. Furthermore, the variability in research designs, population demographics, and outcome measures poses challenges to synthesising the findings into cohesive evidence. Some studies, such as Zhang et al. (2022), lacked standardised protocols for assessing intervention efficacy, which complicates direct comparisons and limits the reliability of their conclusions. Future research should prioritise the development of consistent frameworks for experimental design and reporting. Such efforts would ensure that the field moves towards evidence-based interventions grounded in robust and replicable findings.

4. Discussion and conclusion

In recent years, advancements in wearable devices, haptic feedback systems, and AR/VR technologies have transformed the landscape of somatosensory interactions, particularly in mental health care. These technological developments have enhanced the accessibility, usability, and applicability of non-invasive interventions, creating new opportunities for interdisciplinary approaches to enhance mental well-being. Coinciding with these advancements, there has been a surge in global awareness of mental health issues and demand for innovative therapeutic solutions, as highlighted by the World Health Organization's (2022) emphasis on mental health as a global priority. This review, focused on studies published in or after 2019, captures this pivotal moment in the field when societal and technological factors converged to redefine the role of somatosensory technologies in mental health interventions. By synthesising research from this transformative period, the discussion explores the potential of these innovations while critically examining their implications and limitations for future applications.

Building on this context, the rise in global mental health issues underscores the urgent need for effective therapeutic strategies that seamlessly integrate into our technologically mediated lifestyles. This discussion critically examines the types of somatosensory interactions used to promote mental health and well-being, identifies gaps in the current research, and explores the implications for the design and deployment of these technologies.

Somatosensory interactions encompass a variety of technologies designed to enhance mental health and well-being. These technologies include tactile feedback systems, vibrotactile devices, thermal feedback systems, force feedback devices, and multisensory integration systems. First, tactile feedback systems, such as gloves and vests equipped with actuators, simulate the sensation of touch and have been shown to reduce stress and anxiety. These effects align with the principles of embodied cognition, which propose that physical interactions with the environment influence cognitive and emotional states. By engaging users' tactile senses, these systems enhance self-awareness and emotional regulation, offering a grounding effect that promotes mental well-being. For instance, Haynes et al. (2022) found that a tactile aid that simulated slow breathing was as effective as guided meditation in reducing anxiety. Second, vibrotactile devices, which are often integrated into wearables such as wristbands, deliver sensory stimuli to regulate physiological responses, promoting relaxation and reducing symptoms of anxiety and depression. These devices can be synchronised with therapeutic music or guided meditation to enhance their calming effects. Third, thermal feedback systems use temperature changes to simulate environmental conditions or emotional states. The calming effects of these systems can be understood through the lens of stress reduction theories, which suggest that sensory stimuli, such as warming or cooling sensations, can lower physiological arousal and alleviate stress. By simulating comforting environmental conditions, these devices create a soothing experience that mirrors mindfulness-based practices. Devices might cool down to evoke a sense of calm or warm up to provide comfort, enhancing the realism and emotional impact of virtual environments. Fourth, force feedback devices provide resistance or force against user movements, simulating physical activities that are relaxing or meditative, which can help to ground individuals and provide a sense of physical presence. Fifth, multisensory integration systems combine tactile, vibrotactile, thermal, and force feedback to create highly immersive and interactive experiences. These systems manifest the principles of embodied cognition by engaging multiple sensory pathways simultaneously, fostering deeper cognitive and emotional engagement. When paired with stress reduction techniques, such as guided relaxation protocols, or biofeedback tools that provide real-time data, these technologies can deliver holistic therapeutic experiences. Such designs are particularly effective in enhancing user immersion and long-term adherence to interventions. Research indicates that such interactions can greatly enhance user engagement and the overall effectiveness of mental health interventions.

Despite the promising potential of somatosensory interactions in mental health care, there are several gaps in the current body of research. One of the most pressing challenges is the variability in study designs and reported outcomes across the reviewed papers, which presents significant obstacles to the reliability and generalisability of the findings. For instance, participant demographics varied widely across studies: while some focused exclusively on older adults (e.g., Som et al., 2024), others included children or mixed-age groups (e.g., Hu, 2023).

The studies also differed in their experimental protocols; for example, Haynes et al. (2022) relied on self-reported anxiety levels as outcomes, whereas Béquet et al. (2022) incorporated physiological measures such as heart rate variability. These differences complicate the synthesis of findings, as outcomes measured using subjective scales may not align with objective physiological results. Such variability makes it challenging to develop generalisable conclusions about somatosensory interventions, particularly regarding their efficacy and scalability. This inconsistency may stem from a lack of integration with theoretical models such as biofeedback and CBT. For example, biofeedback principles could provide standardised physiological metrics, such as heart rate variability or cortisol levels, to complement self-reported outcomes, while CBT frameworks could guide the design of interventions to ensure consistency across studies. This diversity, while reflecting the exploratory nature of the field, complicates direct comparisons and the development of universal conclusions. For instance, the studies differed in their participant demographics, experimental protocols, and the metrics used to assess user engagement and well-being. Such inconsistencies can lead to fragmented insights, limiting the ability to synthesise robust evidence about the overall efficacy of somatosensory technologies. Furthermore, the lack of standardised outcome measures makes it difficult to replicate and validate findings, reducing their applicability across broader contexts.

To address these limitations, future research should prioritise the development of standardised frameworks for experimental design and outcome measurement. Such frameworks could incorporate validated self-report tools, such as the GAD-7 for anxiety assessment, alongside objective measures like cortisol levels or heart rate variability. Combining these metrics would enable a holistic evaluation of interventions while ensuring consistency across studies. Moreover, standardising participant recruitment criteria, such as focusing on specific age groups or baseline mental health conditions, could reduce demographic variability. Protocols that specify intervention durations, frequencies, and evaluation points would also improve comparability and facilitate meta-analytic synthesis. Consistent metrics for assessing mental health outcomes, user engagement, and intervention efficacy would enhance the comparability of studies. Furthermore, meta-analytic approaches could provide a structured way to integrate findings from diverse studies. For example, studies evaluating tactile feedback for anxiety reduction (e.g., Béquet et al., 2022; Haynes et al., 2022) could be synthesised to identify common patterns in efficacy, despite differences in demographics or protocols. Such analyses would enable researchers to synthesise robust conclusions about the overall effectiveness of somatosensory technologies and guide the development of standardised intervention guidelines. Additionally, researchers should consider using meta-analytic approaches to synthesise the findings from diverse methodologies, which would provide a clearer picture of the effectiveness and scalability of somatosensory technologies. Addressing these methodological inconsistencies would lead the field towards more reliable, generalisable conclusions that inform the integration of somatosensory interactions into mental health care.

Another significant gap is the lack of long-term studies. Most studies focused on short-term outcomes, which limits our understanding of the sustained impact of these interventions. For instance, Chang et al. (2023) evaluated the immediate effects of a wearable somatosensory device in a single-session study, but the long-term adherence and sustained mental health benefits remain untested. Longitudinal studies could address whether participants continue to engage with these interventions over time and whether the observed benefits, such as reduced anxiety or improved emotional regulation, persist for weeks, months, or years. Furthermore, such studies could explore how factors such as usability, accessibility, and technological obsolescence affect long-term engagement, providing valuable insights for improving intervention designs. Future research should prioritise the inclusion of diverse participant groups, such as children and underrepresented populations, to ensure the broader applicability of findings. Additionally, adopting longitudinal designs grounded in CBT principles could provide insights into the sustained efficacy of these technologies, addressing the current reliance on short-term evaluations. For instance, Som et al. (2024) demonstrated that playing somatosensory games significantly improved elderly participants' happiness and health autonomy. However, further research with larger, more diverse populations is required due to the small sample size.

A closer examination of the reviewed studies reveals several recurring limitations and potential biases that merit critical discussion. Many studies heavily relied on self-reported measures, which can introduce bias, as participants' perceptions may not always align with objective outcomes. Incorporating biofeedback measures, such as heart rate variability or skin conductance, could enhance the objectivity of these findings. By triangulating subjective reports with physiological data, researchers can obtain a more comprehensive understanding of the efficacy of somatosensory interventions. For example, while Haynes et al. (2022) demonstrated the efficacy of a tactile aid in reducing anxiety through self-reports, the absence of physiological data, such as heart rate variability or cortisol levels, limits the robustness of the conclusions. Additionally, several studies used proof-of-concept designs conducted in controlled environments, raising concerns about ecological validity. Technologies tested under idealised conditions may not perform similarly in real-world settings, where factors such as accessibility, technical literacy, and environmental distractions influence outcomes. For instance, Peng et al. (2024) highlighted the benefits of VR-based ASMR triggers for mental well-being but acknowledged challenges related to cost and user adaptation, which could hinder widespread adoption. The lack of longitudinal data across the majority of studies also poses a significant challenge. Short-term evaluations, while useful for initial insights, fail to capture the sustained impacts of somatosensory interventions on mental health. This underscores the need for follow-up studies to examine long-term adherence and efficacy. To address these limitations, future research should adopt larger, more diverse samples and incorporate mixed-methods approaches that combine subjective and objective measures. Additionally, expanding testing to real-world settings and integrating longitudinal designs would enhance the ecological validity and reliability of findings. By addressing these methodological inconsistencies, the field can move towards more robust, generalisable conclusions about the role of somatosensory technologies in mental health care.

The high cost and limited accessibility of advanced technologies such as VR and sophisticated wearables also pose challenges for their widespread adoption. Developing cost-effective alternatives that incorporate theoretical insights, such as simplified biofeedback tools or CBT-guided sensory exercises, could enhance accessibility without compromising therapeutic impact. Additionally, collaboration with healthcare providers and policymakers is essential to create affordable deployment strategies that bridge the gap between research settings and real-world applications. Studies such as those by Kim et al. (2019) and Peng et al. (2024) demonstrate the effectiveness of VR environments in reducing anxiety, but the expense and accessibility issues need to be addressed before these interventions can become more broadly available. Additionally, the reliance on self-report measures in many studies may introduce bias, indicating a need for more objective assessments and biomarkers to provide robust evidence of efficacy. For example, although Haynes et al. (2022) found support for the efficacy of tactile aids using self-reported data, incorporating physiological measures would strengthen the findings.

The current body of literature has several implications for the design and deployment of somatosensory interactions in mental health interventions. There is a clear need for balanced research methodologies that integrate both quantitative and qualitative insights to provide a fuller, more nuanced understanding of the impacts and effectiveness of these technologies. However, the diversity in study designs and methodologies presents both opportunities and challenges. While quantitative studies provide measurable and generalisable insights into efficacy, qualitative research enriches these findings by capturing context-specific user experiences and exploring deeper emotional and behavioural impacts. For example, qualitative approaches, such as focus groups or narrative interviews, have revealed critical design elements that enhance user engagement, which are often overlooked in quantitative analyses. The variability in methodologies – ranging from sample size to outcome measures – highlights the exploratory nature of the field but also underscores the need for standardised protocols to improve comparability and reliability. Future research should adopt mixed-methods approaches to balance numerical data with experiential insights, fostering a more holistic understanding of somatosensory interactions and their impact on mental health outcomes.

To enhance the field's reliability and credibility, a stronger emphasis on evidence-based reasoning is necessary. While quantitative methodologies dominate the current research landscape, qualitative approaches provide invaluable contextual data that reveal critical user insights often overlooked in numerical analyses. For instance, integrating physiological measures such as heart rate variability, cortisol levels, or neurofeedback could strengthen self-reported data on intervention outcomes. Moreover, the inclusion of longitudinal studies would help track the sustainability of mental health improvements over time – a critical limitation in many of the reviewed studies. The consistent use of objective metrics would also reduce variability across studies, enabling more accurate comparisons and meta-analytic syntheses. These methodological enhancements are essential for establishing robust evidence-based practices that ensure the generalisability of findings and facilitate their application in diverse real-world contexts. For instance, integrating objective physiological measures with self-reported data can provide a more comprehensive evaluation of efficacy.

Future research should also aim to balance the focus across a range of age groups and mental health issues to ensure interventions are inclusive and comprehensive. The underrepresentation of children and younger populations in the research highlights a critical area for future studies. Research on somatosensory interaction designs for children, such as the work by She H.L. et al. (2023) and Li et al. (2024), could provide valuable insights into the most effective interventions for supporting their mental and emotional development. Cost-effective solutions should also be explored to make advanced technologies such as VR and sophisticated wearables more accessible. Developing affordable versions of these technologies could broaden their use and impact. Furthermore, combining somatosensory interactions with established therapeutic approaches could enhance overall treatment effectiveness. For example, integrating tactile feedback with CBT principles, as in the study by Chasqueira et al. (2022), would provide a more holistic approach to managing mental health conditions.

In conclusion, somatosensory interactions offer significant potential for mental health interventions. By addressing the identified gaps and focusing on inclusive, long-term, and cost-effective solutions, future research can enhance the effectiveness, accessibility, and applicability of these innovative approaches, making somatosensory technologies a more integral part of mental health care. This review contributes to the field by synthesising diverse findings on somatosensory interaction design and its application in mental health care, highlighting critical gaps and offering a roadmap for future research. By identifying the variability in study methodologies, the lack of long-term evaluations, and the underrepresentation of certain populations (e.g., children and younger adults), this study provides a structured understanding of current challenges. In addition, the integration of theoretical frameworks such as embodied cognition and biofeedback principles underscores the importance of grounding future technological developments in well-established psychological and physiological theories.

To advance the field, this review recommends prioritising the development of standardised metrics for evaluating intervention outcomes, including user engagement, physiological responses, and mental health improvements. Moreover, integrating longitudinal designs and mixed-methods approaches would allow researchers to balance numerical efficacy data with qualitative insights into users' experiences. Expanding the inclusivity of studies by involving more diverse participant groups would enhance the generalisability of findings and ensure that somatosensory interventions cater to a wide range of mental health needs. Finally, this review emphasises the necessity of designing cost-effective and accessible technologies that can be seamlessly integrated into real-world contexts, bridging the gap between controlled research environments and practical applications. By addressing these recommendations, future research can build a robust evidence base that informs the effective and equitable deployment of somatosensory technologies in mental health care.

CRediT authorship contribution statement

Ming Cheung: Writing – original draft, Writing – review & editing, Conceptualization, Methodology, Formal analysis, Project administration, Funding acquisition. **Guobin Xia:** Writing – original draft, Writing – review & editing, Methodology, Formal analysis. **Zhan Xu:** Investigation, Formal analysis.

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Declaration of competing interest

The authors declare no conflicts of interest related to this study.

Data availability

The authors do not have permission to share data.

References

Barcelos, A. M., Kargas, N., Maltby, J., Hall, S., Assheton, P., & Mills, D. S. (2021). Theoretical foundations to the impact of dog-related activities on human hedonic well-being, life satisfaction and eudaimonic well-being. *International Journal of Environmental Research and Public Health, 18*(23), Article 12382.

Barrios-O'Neill, D., & Pakalkaitė, J. (2022). Exploring next-generation touch-rich interactions for consumer well-being. *Proceedings of EVA London*, 221–228.

Béquet, A. J., Hidalgo-Muñoz, A. R., Moreau, F., Quick, J., & Jallais, C. (2022). Subtle interactions for distress regulation: Efficiency of a haptic wearable according to personality. *International Journal of Human-Computer Studies, 168*, Article 102923.

Brelet, L., & Gaffary, Y. (2022). Stress reduction interventions: A scoping review to explore progress toward use of haptic feedback in virtual reality. *Frontiers in Virtual Reality, 3*, Article 900970.

Chang, C. H., Lien, W. C., Chiu, T. P., Yang, T. H., Wei, C. C., Kuo, Y. L., … Lin, Y. C. (2023). A novel smart somatosensory wearable assistive device for older adults' home rehabilitation during the COVID-19 pandemic. *Frontiers in Public Health, 11*, Article 1026662.

Chasqueira, A., Neves, M., Rafael, S., & Melo, A. (2022). Kub-E: An interactive design device for children with panic disorder. *International Journal of Child-Computer Interaction, 31*, Article 100423.

Claisse, C., Umair, M., Durrant, A. C., Windlin, C., Karpashevich, P., Höök, K., … Sas, C. (2022). Tangible interaction for supporting well-being. *Proceedings of 2022 CHI conference on human factors in computing systems*. Article 100.

Coulter, J. (2023). Feeling well: Using the augmented touch of e-textiles to embody emotion and environment as a "self-health" intervention for female student wellbeing. *Journal of Textile Design Research and Practice, 11*(1-2), 81–110.

DaudéN Roquet, C., & Sas, C. (2021). Interoceptive interaction: An embodied metaphor inspired approach to designing for meditation. *Proceedings of the 2021 CHI conference on human factors in computing systems*. Article 265.

DaudéN Roquet, C., Theofanopoulou, N., Freeman, J. L., Schleider, J., Gross, J. J., Davis, K., Townsend, E., & Slovak, P. (2022). Exploring situated and embodied support for youth's mental health: Design opportunities for interactive tangible device. *Proceedings of the 2022 CHI conference on human factors in computing systems*. Article 331.

Deusdado, L. D., & Antunes, A. F. (2023). Virtual reality haptic device for mental illness treatment. *Procedia Computer Science, 219*, 1112–1119.

Eapen, V., Stylianakis, A., Scott, E., Milroy, H., Bowden, M., Haslam, R., & Stathis, S. (2023). Stemming the tide of mental health problems in young people: Challenges and potential solutions. *Australian and New Zealand Journal of Psychiatry, 57*(4), 482–488.

Gallace, A., & Girondini, M. (2022). Social touch in virtual reality. *Current Opinion in Behavioral Sciences, 43*, 249–254.

Günther, S., Skogseide, A., Buhlmann, R., & Mühlhäuser, M. (2024). Assessing the influence of visual cues in virtual reality on the spatial perception of physical thermal stimuli. *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, Article 635.

Haynes, A. C., Lywood, A., Crowe, E. M., Fielding, J. L., Rossiter, J. M., & Kent, C. (2022). A calming hug: Design and validation of a tactile aid to ease anxiety. *PLoS One, 17*, Article 0259838.

Hennemann, S., Witthöft, M., Kleinstäuber, M., Böhme, K., Baumeister, H., Ebert, D. D., & Probst, T. (2022). Somatosensory amplification moderates the efficacy of internet-delivered CBT for somatic symptom distress in emerging adults: Exploratory analysis of a randomized controlled trial. *Journal of Psychosomatic Research, 155*, Article 110761.

Holt, S. (2023). Virtual reality, augmented reality and mixed reality: For astronaut mental health; and space tourism, education and outreach. *Acta Astronautica, 203*, 436–446.

Hu, H. J. (2023). A study of interactive design games to enhance the fun of muscle strength training for older adults. In Q. Gao, & J. Zhou (Eds.), *Human aspects of IT for the aged population* (pp. 420–434). Springer.

Jacobs, N. (2020). Capability sensitive design for health and wellbeing technologies. *Science and Engineering Ethics, 26*, 3363–3391.

Kasai, R., Itoh, N., Kamijo, F., Kano, T., Shimamine, T., Ogino, M., … Mizuno-Matsumoto, Y. (2020). Assessment of somatosensory sensitivity and activity of the electroencephalogram using body surface electrical stimulation in virtual reality environments. *Electronics and Communications in Japan, 103*(11-12), 71–82.

Kim, Y. I., Jung, S. Y., Min, S., Seol, E., Seo, S., Hur, J. W., … Kim, G. J. (2019). Visuo-haptic-based multimodal feedback virtual reality solution to improve anxiety symptoms: A proof-of-concept study. *Psychiatry Investigation, 16*(2), 167–171.

Li, X. Y., & Gan, B. Q. (2021). Research on intelligent somatosensory interaction devices based on virtual reality technology. *Journal of Physics Conference Series, 2005*(1), Article 012097.

Li, Z. M., Ramli, S. H., Romli, M. H., Ahmad Azmeer, R., Sulaiman, P. S., Lin, C., … You, D. (2024). Focus group discussion on factors for development of somatosensory games on hand function training for self-care ability of children with autism. *International Journal of Developmental Disabilities*, Article 2301188.

Lim, C. K. (2021). An emotional tactile interaction design process. In M. Kurosu (Ed.), *Human-computer interaction* (pp. 384–395). Springer.

Lu, Y. C., & Liao, Z. (2023). Towards happy housework: Scenario-based experience design for a household cleaning robotic system. *ICST Transactions on Scalable Information Systems, 10*(3), Article e12.

Ma, D. Y., & Li, F. (2019). Design and research of somatosensory wristband based on people with language barriers. *IOP Conference Series: Materials Science and Engineering, 573*(1), 012092.

Matheus, K., Vázquez, M., & Scassellati, B. (2022). A social robot for anxiety reduction via deep breathing. *Proceeedings of the 2022 IEEE international conference on robot and human interactive communication*, 89–94.

Meijer, L. L., Schielen, Z. A., Van Ree, K. Y., & Dijkerman, H. C. (2021). Affective touch reduces electrically induced itch experience. *Frontiers in Medicine, 8*, Article 628020.

McDaniel, T., & Panchanathan, S. (2020). Therapeutic haptics for mental health and wellbeing. In T. McDaniel, & S. Panchanathan (Eds.), *Haptic interfaces for acccessibility, health, and enhanced quality of life* (pp. 149–181). Springer.

Peng, D. Y., Person, T., Shen, X. M., Pai, Y. S., Barbareschi, G., Li, S. Y., & Minamizawa, K. (2024). Impact of Vibrotactile triggers on mental well-being through ASMR experience in VR. In H. Kajimoto, et al. (Eds.), *Haptics: Understanding touch; technology and systems; applications and interaction* (pp. 398–410). Springer.

OECD and World Health Organization. (2022). *Health at a glance: Asia/Pacific 2022: Measuring progress towards universal health coverage*. OECD Publishing.

Rodway, C., Tham, S. G., Richards, N., Ibrahim, S., Turnbull, P., Kapur, N., & Appleby, L. (2023). Online harms? Suicide-related online experience: A UK-wide case series study of young people who die by suicide. *Psychological Medicine, 53*(10), 4434–4445.

She, H. L., Cao, X. L., Guo, G. S., Jiang, Y., Liu, Y., & Zhang, W. P. (2023). Research on the design of somatosensory interactive games for autistic children based on art therapy. *Frontiers in Psychiatry, 14*, Article 1207023.

She, Y. Y., Wang, Q., Liu, F., Lin, L., Yang, B. R., & Hu, B. (2023). An interaction design model for virtual reality mindfulness meditation using imagery-based transformation and positive feedback. *Computer Animation and Virtual Worlds, 34*(1), 2184.

Shenoy, P. (2023). A system for regulation of anxiety-based symptoms. *Proceedings of the global conference on information technologies and communications*. Article 10426204.

Slovak, P., Antle, A., Theofanopoulou, N., DaudéN Roquet, C., Gross, J., & Isbister, K. (2023). Designing for emotion regulation interventions: An agenda for HCI theory and research. *ACM Transactions on Computer-Human Interaction, 30*(1), 1–51.

Smith, A., Ward-Cherrier, B., Etoundi, A., & Pearson, M. J. (2022). Feeling the pressure: The influence of vibrotactile patterns on feedback perception. *Proceedings of the 2022 IEEE/RSJ international conference on intelligent robots and systems*, 634–640.

Som, H. M., Hanafi, H. F., & Savita, K. S. (2024). A comprehensive review of user experience research on somatosensory games for older adults. *Proceedings of the 2024 International conference on computing, communication, control and automation*, Article 10775083.

Villena-Gonzalez, M. (2023). Caresses, whispers and affective faces: A theoretical framework for a multimodal interoceptive mechanism underlying ASMR and affective touch: An evolutionary and developmental perspective for understanding ASMR and affective touch as complementary processes within affiliative interactions. *BioEssays, 45*(12), Article 2300095.

Wagener, N., Ackermann, A., Savino, G. L., Dänekas, B., Niess, J., & Schöning, J. (2022). Influence of passive haptic and auditory feedback on presence and mindfulness in virtual reality environments. *Proceedings of the 2022 international conference on multimodal interaction*, 558–569.

Wang, W. Z., Zou, J. W., & Fang, Y. (2021). Design and evaluation of a somatosensory hat: An emotional semantic perspective. *AATCC Journal of Research, 8*, 20–29.

Woodward, K., Kanjo, E., & Brown, D. (2019). Challenges of designing and developing tangible interfaces for mental well-being. *Proceeedings of the 2019 CHI workshop: New directions for IoT: Automate, share, build, and care*. Article 3290605.

Woodward, K., Kanjo, E., Brown, D. J., & Inkster, B. (2020). *TangToys: Smart toys to communicate and improve children's wellbeing. Proceedings of the 2020 ACM international symposium on wearable computers*, 497–449.

World Health Organization. 2022. COVID-19 pandemic triggers 25% increase in prevalence of anxiety and depression worldwide. Available from: https://www.who.int/news/item/02-03-2022-covid-19-pandemic-triggers-25-increase-in-prevalence-of-anxiety-and-depression-worldwide.

Yang, W. H., Chen, Y. Y., Lung, C. H., & Han, P. H. (2022). Innovative remote interactive device conceptual design based on tactile feedback to alleviate loneliness of the elderly. *Proceedings of the 2022 IEEE international conference on consumer electronics*, Article 9869256.

Yaseen, A., & Timoney, J. (2022). Possibilities emerging on the trajectory from IoT to IoMusT: Enabling ubiquitous musical interactions for wellbeing. *Proceedings of the 3rd international workshop on empowering people in dealing with Internet of Things ecosystems*, 21–25.

Yu, C. W., Rau, P. L. P., & Liu, X. Q. (2020). Development and preliminary usability evaluation of a somatosensory square dance system for older Chinese persons: Mixed methods study. *JMIR Serious Games, 8*(2), Article e16000.

Zhang, Y. H., Han, T., Ding, Y., & Zhao, S. Y. (2022). Design of somatosensory interactive balance training exergame for the elderly based on Tai Chi. In Q. Gao, & J. Zhou (Eds.), *Human aspects of IT for the aged population. Technology in everyday living* (pp. 305–319). Springer.

Zhu, Y. H., Zhang, Y., Wang, Y. W., & Trivic, Z. (2021). The square dance in China: How sensory design can foster inter-generational interaction and improve older adults' wellbeing. *Journal of Urban Design and Mental Health, 7*, Article 7.