

Application of Haptic Gloves in an Interactive Environment as Support for Hand Functional Intervention

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Abstract: This master's thesis explores the application of the Manus Quantum Metagloves as a tool for hand rehabilitation. Through data analysis, three key parameters were evaluated: joint range of motion, joint velocity, and abduction-adduction movements. The results show specific joint limitations, especially in the interphalangeal and metacarpophalangeal joints, as well as functional patterns consistent with anatomy and clinical practice. In addition, a virtual environment was designed for therapeutic purposes. This study validates the potential of using motion capture technologies as an objective complement in the functional assessment of the hand, providing value both in clinical and research settings.

1 Introduction

The hand is one of the most complex and functional structures of the human body. It allows us to explore the environment, communicate, work, create, care, and actively participate in daily life occupations. Through the hand, intentions, emotions, and independence are expressed. Therefore, when it is affected by an injury, illness, or limitation, its impact goes far beyond the physical dimension: it limits autonomy, self-esteem, and participation in daily life.

Hence, hand rehabilitation becomes a fundamental process. It not only seeks to restore movement or strength but also to recover functionality and quality of life. Each recovered gesture represents an opportunity to resume daily, work-related, or personal activities with greater autonomy Lerma et al. (2016).

In recent years, technological advances have opened new possibilities in the therapeutic field. The integration of haptic devices, interactive environments, and motion capture systems is transforming the way rehabilitation is approached. These tools allow not only the design of more dynamic and motivating interventions but also the recording of objective data that enriches clinical analysis, fostering personalized treatment and enabling more individualized follow-up of the user Sabater et al. (2008). This project emerges precisely at that intersection between clinical practice and technology. For this purpose, it proposes a system that combines an interactive environment with haptic technology, using the Manus Quantum Metagloves Manus Technology Group (2025) as a potential therapeutic tool in hand rehabilitation.

For this reason, this project aims to address four main objectives. First, to explore the use of the Manus Quantum Metagloves in an interactive environment designed to support hand rehabilitation processes, integrating technology and meaningful participation as the basis for a person-centered intervention, while simultaneously collecting objective data that adds clinical value to practice.

Second, to develop an interactive game environment that motivates the user and encourages participation in activities oriented toward the rehabilitation of functional hand use.

Third, to integrate the Manus Quantum Metagloves as a technological tool within the therapeutic process, evaluating their applicability and feasibility in a real clinical context.

Finally, to analyze the metrics recorded by the gloves, such as joint ranges of motion, velocity, and movement patterns, with the purpose of complementing the clinical reasoning of professionals and supporting decision-making in the field of rehabilitation.

2 Materials and Methods

2.1 Materials

Manus Quantum Metagloves

The Manus Quantum Metagloves represent an evolution in motion capture and interaction with virtual environments, mainly used in areas such as virtual reality, industrial simulation, video games, and technological research. They are designed to provide precise and stable reading of finger movements using a magnetic sensor system, allowing both absolute and relative tracking of the phalanges without external cameras or additional systems Manus Technology Group (2025).

One of their main features is low latency, providing near real-time response during interactive tasks. In addition, their Plug & Play architecture allows simple integration with Unity Unity Technologies (2025) or Unreal Engine Epic Games (2025). Although these gloves are mainly intended for sectors such as robotics or VR, their high accuracy in finger tracking has enabled their application in the clinical field, particularly for the analysis of range of motion and fine motor rehabilitation.

Manus Core

To capture hand movements, the Manus Core software was used. This tool manages the gloves, including calibration, real-time visualization, environment configuration, and data export. It requires a user account and an active DEMO license, enabled through a USB dongle Manus (2025a). In this project, version 2.5.1 of Manus Core Manus Meta (2025a) was used. Although version 3.0.1 is currently available, the older version was maintained due to compatibility issues, since the dongle did not properly recognize the most recent release.

Unity

Unity is a widely used platform for developing interactive environments, especially in video games, simulation, and virtual reality Unity Technologies (2025). In this project, it was used to design a three-dimensional environment to display hand movements captured by the Manus gloves. The availability of a specific Manus Core plugin for Unity Manus Meta (2025b) facilitated seamless integration. Unity version 2021.3.32f1 LTS was chosen for its stability and compatibility with Manus Core v2.5.1.

RStudio

RStudio is an integrated development environment (IDE) for the R programming language, used here for processing and organizing the data obtained Posit PBC (2025). Its interface allows efficient importing, visualization, and structuring of large data sets, supporting subsequent analysis of the metrics recorded by the Manus gloves.

2.2 Methods

Interactive System Design

The interactive environment was designed with a functional and therapeutic focus, aimed at evaluating simple motor patterns such as reaching and eye-hand coordination through interaction with visual stimuli. The scene consisted of a white table with two virtual buttons (red and blue). Pressing either button with the hand triggered a color change in the table. This behavior was implemented with a custom script that dynamically changed the table's material depending on the activated button.

To integrate real hand movements into the virtual environment, prefabs and scripts from the official Manus Core plugin (v2.5.1) Manus (2025a) were used, including `ManusHand_L`, `ManusHand_R`, `HandHaptics`, `ColliderGenerator`, `GrabbableObject`, and `InteractionHand`. Buttons were added from the plugin's interaction folder using the `PushButton` prefab, which includes the `PushButton`, `CollisionArea`, and a `BoxCollider`. These components enabled rapid and effective implementation of interaction without coding collision logic from scratch.

A start menu was also designed, controlled through another custom script, to initialize the game. Although the system was not applied in a clinical population, functional validations were carried out with volunteer participants to verify the correct mapping of real to digital movements.

Integration with Manus Core

To connect the Manus Quantum Metagloves Manus Technology Group (2025) with the system, the USB dongle was plugged in Manus (2025a). Each glove was then calibrated individually following the software instructions.

After calibration, virtual hands were displayed, including finger flexion values in degrees. Real-time motion recording was then activated, logging data at a frequency of 60 FPS. After each session, data were exported in .csv format, using "space" as a separator to avoid import errors Manus (2025b).

Metric Selection

The metrics were defined after consultations with an occupational therapist specialized in hand rehabilitation to identify clinically relevant parameters. Three main metrics were selected:

- Finger range of motion
- Maximum joint velocity
- Maximum finger abduction–adduction

Data Collection

Data collection was carried out in two phases using Manus Core. In the first phase, conducted at the CITIC research center, volunteers with pre-existing hand limitations participated. During these sessions, the gloves were fitted, calibrated, and tested to validate stable data capture. Sessions lasted 2–3 minutes and involved basic functional gestures such as individual finger flexion, abduction–adduction movements, and global gestures like claw-hand or full fist closure. This allowed validation of joint speed and range recording.

Data Processing

Data processing was conducted entirely in RStudio. Files exported from Manus Core in .csv format were initially comma-delimited, as recommended in the software manual Manus

(2025b). However, errors arose due to the comma also being the decimal separator in the operating system. To address this, “space” was set as an alternative delimiter. Files were later converted to Excel (.xlsx) for clearer visualization and easier manipulation during R analysis.

During processing, variables corresponding to the three main metrics were selected: flexion, angular velocity, and lateral spread. Columns labeled with `Flex` and the joint name were used for flexion analysis (degrees); those ending in `AngularVelocity` for velocity (degrees/second); and those with `Spread` for abduction–adduction (degrees).

Maximum values were extracted for each joint, distinguishing between hands and participants. Data integrity was preserved by analyzing raw files. Analysis was performed with R libraries: `readxl` for importing, `dplyr` for organizing and filtering, and `ggplot2` for visual comparative graphs.

2.3 Theoretical Framework: Occupational Therapy

This project was grounded in the Model of Human Occupation (MOHO), a theoretical framework in occupational therapy which proposes that participation in meaningful occupations is essential to health and well-being Kielhofner (2008). According to MOHO, occupational performance arises from the interaction of three components: volition, habituation, and performance capacity, all in constant interaction with the environment.

The intervention proposed here, based on haptic gloves in an interactive environment, aligns with MOHO principles by facilitating active participation in meaningful activities adapted to individual capacities and interests. Technology was introduced as a complementary resource to enhance motivation, promote functional hand use, and support autonomy in daily activities.

2.4 Service-Learning Project

This Master’s Thesis was developed within a Service-Learning (ApS) project promoted by the Universidade da Coruña. The ApS methodology combines academic training with community service, linking knowledge acquisition with socially relevant applications.

The project was carried out in collaboration with an occupational therapist specialized in hand rehabilitation and included three voluntary participants who tested the proposed activity. This validated the system from a practical perspective, ensuring that technological development addressed real needs and contributed to user well-being.

The ApS approach also reinforced the university’s social commitment, fostering values such as responsibility, empathy, and active involvement in improving quality of life.

3 Results

3.1 Range of Motion

Table 1 shows the functional ranges of motion used as reference values Tortora and Derrickson (2011).

Table 1: Reference functional ranges of motion

Joint	Min (°)	Max (°)
CMC	45	50
MCP	80	90
PIP	100	115
DIP	80	90

Compared to these references, all three participants showed limitations in one or more finger joints. The most affected were MCP and DIP joints, particularly in the right hand. Participant 01 presented restrictions in both hands, especially in MCP flexion of index, ring, and little fingers. Participant 02 showed reduced values in DIP joints, and Participant 03 in thumb PIP and DIP joints. Overall, DIP and MCP were the most commonly limited.

3.2 Joint Velocity

Table 2 summarizes the fastest joints identified per participant, reflecting fluency of movement. Most maximum values were observed in the left hand, except for Participant 02, where the right hand showed the peak velocity.

Table 2: Joints with maximum angular velocity per participant

Participant	Hand	Joint
P01	Right	Middle_MCP
P01	Left	Middle_MCP
P02	Right	Index_PIP
P02	Left	Thumb_CMC
P03	Right	Pinky_MCP
P03	Left	Middle_PIP

3.3 Abduction–Adduction

In all participants, the thumb CMC joint consistently presented the greatest spread values, confirming its central role in functional hand mobility.

4 Discussion

This study analyzed range of motion, joint velocity, and abduction/adduction using high-precision haptic gloves. From the perspective of occupational therapy in hand rehabilitation, the results not only provide quantifiable data but also reinforce clinical observations of common functional limitations after surgery, injury, or degenerative processes.

Regarding range of motion, the most frequently limited joints were metacarpophalangeal (MCP) and distal interphalangeal (DIP), especially in the ring and little fingers. This finding is consistent with clinical literature identifying these joints as particularly vulnerable to post-surgical stiffness and overuse, given their stabilizing and compensatory functions in grip tasks Valente-Pineda et al. (2021). The use of Manus Quantum Metagloves enabled more objective and detailed evaluation compared to visual inspection or goniometers, which are common but prone to interpretation errors and patient subjectivity Surangsrirat et al. (2022).

For joint velocity, the analysis showed that the joints reaching the highest angular speed were, in all cases, MCP or interphalangeal joints of the index and middle fingers. This result is functionally coherent, as these fingers are essential for rapid, precise actions such as typing, pressing buttons, or manipulating small objects. From a therapeutic standpoint, identifying which joints maintain better velocity may guide interventions that leverage compensatory mechanisms or strengthen specific skills.

The abduction–adduction analysis revealed that the carpometacarpal (CMC) joint of the thumb was the most active in all participants. This matches anatomical knowledge of the thumb as the central element for grasp and tridimensional pinch. Preserving its mobility is a key goal in hand rehabilitation programs Cerón et al. (2012).

Implementing motion-capture systems like Manus represents a significant step forward in clinical evaluation. These tools provide real-time metrics, contactless joint performance visualization, and support for designing targeted interventions. As noted in other rehabilitation technology studies, integrating haptic sensors and measurement platforms opens pathways for personalized treatment, objective progress tracking, and patient motivation through biofeedback Surangsirat et al. (2022).

Overall, the findings support the feasibility of haptic technologies in rehabilitation and highlight the value of combining clinical reasoning with technological tools for decision-making in therapy.

4.1 Limitations

Despite positive outcomes, this study presents several limitations.

First, physical limitations of the device were identified. The Manus Quantum Metagloves are difficult to fit, especially for individuals with stiffness, deformities, or muscular atrophy. Moreover, their standard size is only suitable for adults, excluding pediatric populations or adults with smaller hands.

Second, the main technical obstacle was the Manus Core software. The demo version restricted access to advanced features, such as digital goniometer visualization, preventing direct comparison with traditional clinical measures.

Data export also posed issues. Although the technical manual recommended CSV export with commas, decimal commas caused parsing errors and loss of some data. Switching to space delimiters improved stability but still led to partial data loss.

Finally, although an interactive environment (game) was developed to test glove use in playful evaluation, it could not be applied in real clinical contexts due to logistical constraints. Installation and setup required extra time not available in scheduled sessions. In practice, participants preferred direct evaluation with the gloves rather than the virtual game, limiting its usability.

These limitations do not invalidate the results but highlight the need to improve accessibility, compatibility, and validation in real clinical contexts for future studies.

5 Conclusion

This study explored the potential of the Manus Quantum Metagloves as a digital evaluation tool for hand movement, focusing on three key parameters: range of motion, joint velocity, and abduction–adduction movements.

Through data analysis performed in RStudio, the gloves demonstrated the ability to detect specific functional limitations in distal interphalangeal joints, particularly in participants with pathological backgrounds. Moreover, the joints showing the greatest restrictions corresponded mostly to those clinically known as prone to stiffness in musculoskeletal conditions, such as proximal interphalangeal (PIP) and metacarpophalangeal (MCP) joints, aligning with existing clinical knowledge.

The study also identified variability in movement velocity during opening and closing tasks, with certain joints performing more efficiently than others. Regarding abduction and adduction, the thumb consistently displayed the greatest amplitude, which is coherent with its anatomical role as the most mobile and functional digit.

Overall, the findings reinforce the notion that motion-capture technologies applied to the hand can provide objective, reliable, and complementary metrics to traditional clinical observation. Despite technical limitations related to software and data export, the results support the use of such systems in clinical research and highlight their potential for personalized evaluation in hand rehabilitation.

In conclusion, integrating haptic technologies like the Manus Quantum Metagloves represents a significant step forward in functional hand assessment, provided that these tools are

adapted to clinical needs and validated against traditional methods. This study represents an initial step toward such validation.

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