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Tele-Monitoring and Tele-Rehabilitation of the Hand in Hemiplegic Patients: A Preliminary Study

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Abstract

Hemiplegia after stroke, one of the consequences of the acute loss of focal brain functions, is a syndrome clinically characterized by a deficit of voluntary motor activity in one half of the body. Many studies highlight the benefits of rehabilitation treatments on the partial recovery of motor function, but also how the effects of this treatment are not lasting unless frequently stimulated by maintenance activities. This study describes a methodological approach, based on non-invasive technologies, to the quantitative evaluation of motor tasks defined in the MESUPES-Hand section, which could allow targeted and monitored stimulation of patients in home environment, reducing or dilating new hospitalizations and further traditional rehabilitation treatments over time. Preliminary results indicate that the system detects quantitative and qualitative differences between hemiplegic and healthy hand, the starting point for the automatic evaluation of motor function and its progress through remote rehabilitation.

Activity Description / Materials and Method

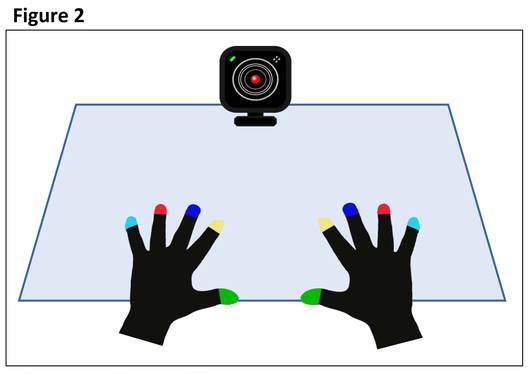
The primary objective of this study is to stimulate and maintain the motor status, reached by hemiplegic patients after an intensive hospitalization, over time through a home evaluation and rehabilitation work. One of the fundamental pillars to achieve this goal is the automatic evaluation of the hand and fingers movement during the execution of the motor tasks defined by the MESUPES-Hand scale (Fig.1): this will make it possible to objectively quantify any progress or worsening of motor performance remotely and more frequently according to the personalized home rehabilitation protocol. To this end, a motion capture system based on RGB-Depth optical devices and light gloves with colored markers was developed (Fig.2). An ad-hoc hand tracking algorithm allows, through Computer Vision techniques, to recognize and trace the 3D trajectories of the colored markers that correspond to the movement of specific points of the hand (e.g., fingertips) involved in the motor tasks defined by the MESUPES-Hand scale (Fig.3).
10 Hemiparetic patients post acute or subacute stroke (Age: 61±13; Sex: 3 Females and 7 Males, Side: 4 left and 6 right) with minor disability of the upper limbs and lower limbs (possibility of walking), with Mini-Mental State Examination (MMSE)> 26.
Ten patients, seated at the table, worn gloves with colored markers and performed the sequence of motor tasks, first with the healthy hand and then with the hand with hemiplegia, while the system automatically captured the 3D trajectories (Fig.4) of the movement of the hand and fingers. Kinematic parameters were extracted from the 3D trajectories of movement: in this way, a general objective characterization of the motor performance was obtained. This allows an immediate comparison for example between healthy hand and hand with hemiplegia; or between "pre" and "post" rehabilitative treatment; or between "post" rehabilitation condition and follow-up after a few months. Additionally, for motor tasks 8 and 9 (Fig.5)involving the use of a dice, computer vision methods were applied to RGB images to detect points marked by the dice faces and identify if there have been rotations as required by the motor activity. This information allows to verify both the correct execution of the required motor activity and to assign a score to motor performance according to the evaluation criteria indicated by the MESUPES-Hand scale. This information allows to verify the correct execution of the motor activity; to assign a score to motor performance according to the evaluation criteria indicated by the MESUPES-Hand scale; but above all to have quantitative measures that provide a more complete view of motor performance to support clinical evaluation.

Figure 1

MESUPES-hand test
1. Pinch grip fingers 1 and 2
2. Wrist extension
3. Opposition fingers 1 and 5
4. Extension 3rd finger
5. Spread fingers 2 and 3
6. Extension 5th finger*
7. Lift little bottle 2 cm
8. Rotate dice fingers 1 and 2
9. Index top + rotate dice

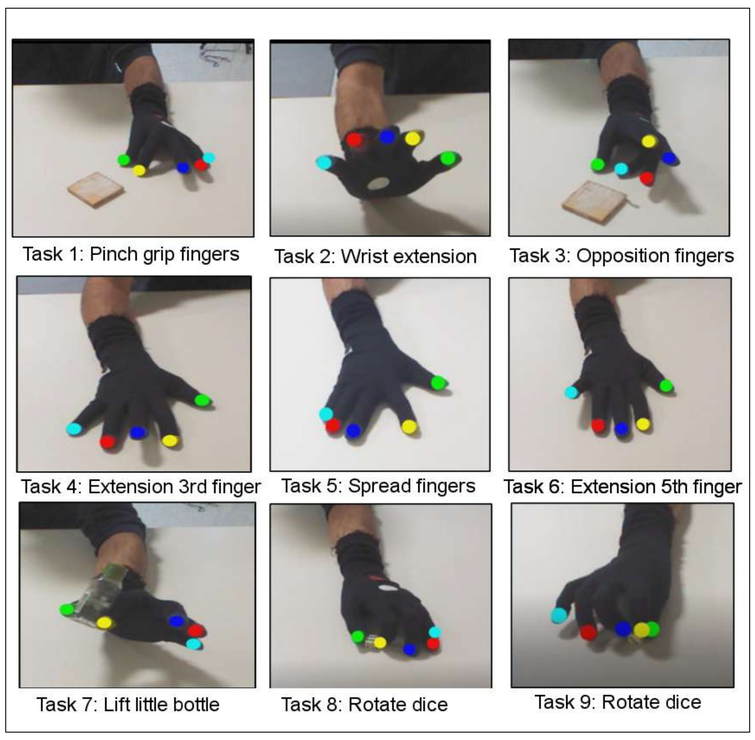
Motor Tasks defined by the MESUPES-Hand scale

Figure 2



Setup of Hand Tracking acquisition system: hands on table, gloves with colored markers, RGB-Depth sensor to capture hand and fingers movement.

Figure 3

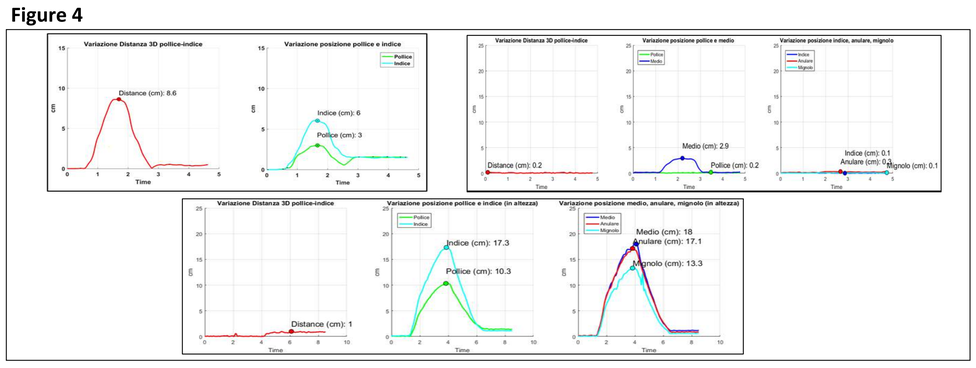


Tracking of hand and fingers movement while performing the motor tasks of MESUPES-Hand

Findings / Impact

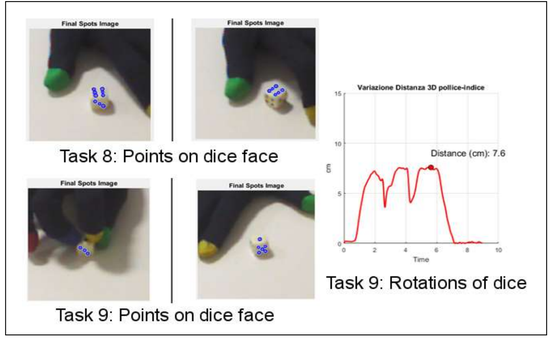
The activity carried out so far has made it possible to assess the feasibility of an objective assessment of the MESUPES-Hand scale in subjects with stroke consequences. A non-invasive and low-cost motion capture system and hand tracking algorithm have been developed using Computer Vision techniques that allow for the accurate tracking of hand and fingers movement during the execution of motor tasks defined in MESUPES-Hand scale.
Kinematic parameters have been defined to objectively and automatically (Fig.6) characterize the motor performance, highlight differences in motor function between healthy hand and hand with hemiplegia and assign scores according to the evaluation criteria indicated by MESUPES-Hand scale.
The preliminary results make us embark on a path of rehabilitation and evaluation at home capable of maintaining a functional standard and preventing the risk of functional decline.
This study represents a first step of a long-term project aimed at the remote rehabilitation of post-stroke patients.

Figure 4



Example of 3D trajectories of hand and fingers according to motor activity: Task 1 (top left), Task 4 (top right) and Task 2 (bottom center)

Figure 5



Detection of points on dice face to evaluate rotation of dice for Task 8 and 9 of MESUPES-Hand

Figure 6

Automatic scores for Subject

MESUPES-HAND	HEALTHY HAND	HEMIPLEGIC HAND
Task 1	2	2
Task 2	2	2
Task 3	2	2
Task 4	2	2
Task 5	2	1
Task 6	2	2
Task 7	2	1
Task 8	2	1
Task 9	2	0

Automatic vs Clinical scores for Subject

	SCORES	HEALTHY HAND	HEMIPLEGIC HAND
AUTOMATIC SYSTEM	Task 1-6	12/12	11/12
	Task 7-9	6/6	2/6
	Total	**18/18**	**13/18**
CLINICAL	Task 1-6	12/12	10/12
	Task 7-9	6/6	3/6
	Total	**18/18**	**13/18**

Example of scores automatically assigned by the system to each motor task of MESUPES-Hand (left); comparison between Automatic and Clinical global evaluation of MESUPES-Hand

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