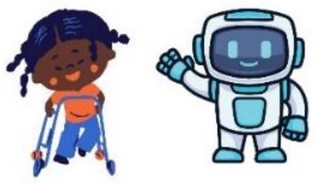
Implementing and Testing the Novel REHAB-PAL System on Unimpaired Population: Towards Rehabilitation Engagement at Home with a Socially Assistive Robot for Pediatric Adherence

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Introduction

Cerebral palsy (CP) is the most common motor disability in childhood, affecting 500,000 children under the age of 18 only in the United States, and 10,000 babies born each year are diagnosed with this pathology [1]. Cerebral palsy originates from an injury that occurs during the brain development in the prenatal, perinatal, or postnatal period [2]. Due to this neurological condition, patients are affected by motor disabilities; therefore, repeated sessions of rehabilitation are prescribed for their improvement [3]. **At-home sessions of rehabilitation** could help children with cerebral palsy perform **extensive and repetitive rehabilitative exercise, promoting the adherence to the therapy** [4]. Thanks to their interactive skills, **Socially Assistive Robots could engage patients in the exercises** during at-home sessions of rehabilitation [5].

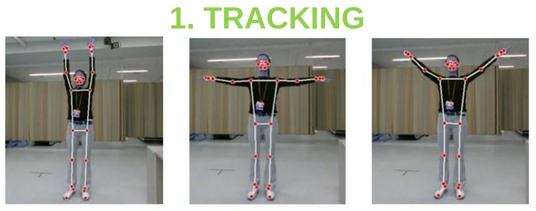


Methodology

REHAB-PAL system:

An interactive solution for home-based rehabilitation in children with cerebral palsy

1. TRACKING

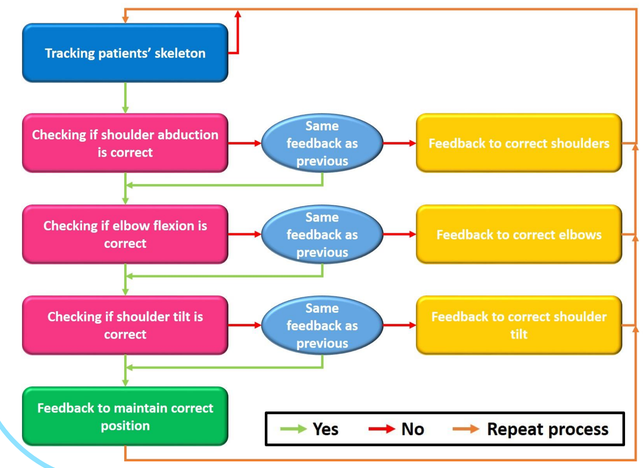


2. LOOK-UP TABLE FOR MOVEMENT ASSESSMENT

Physical Exercise	Shoulder Abduction	Elbow Flexion	Shoulder Tilt
Hands Up	[170°, 180°]	[0°, 9.9°]	[0, 0.0049]
	[165°, 169.9°]	[10°, 14.9°]	[0.005, 0.0099]
	[160°, 164.9°]	[15°, 19.9°]	[0.01, 0.019]
	[0°, 159.9°]	[20°, 150°]	> 0.02
Hands T	[85°, 94.9°]	[0°, 9.9°]	[0, 0.0049]
	[80°, 84.9°] & [95°, 99.9°]	[10°, 14.9°]	[0.005, 0.0099]
	[70°, 79.9°] & [100°, 109.9°]	[15°, 19.9°]	[0.01, 0.019]
	[0°, 69.9°] & [110°, 180°]	[20°, 150°]	> 0.02
Hands Y	[130°, 139.9°]	[0°, 9.9°]	[0, 0.0049]
	[125°, 129.9°] & [140°, 144.9°]	[10°, 14.9°]	[0.005, 0.0099]
	[115°, 124.9°] & [145°, 154.9°]	[15°, 19.9°]	[0.01, 0.019]
	[0°, 114.9°] & [155°, 180°]	[20°, 150°]	> 0.02

Label	Accurate	Mild	Moderate	Severe
Score	3	2	1	0

3. DECISIONAL STRATEGY FOR FEEDBACK



4. ROBOT CHARACTERIZATION



- Showing movements
- Giving customized feedback
- Evaluating movement execution

TESTING system:

11 physical therapists and rehabilitation experts



Exercise Type	Before Feedback	After Feedback
Accurate	✓	✓
Correction	✗	✓
Erroneous	✗	✗

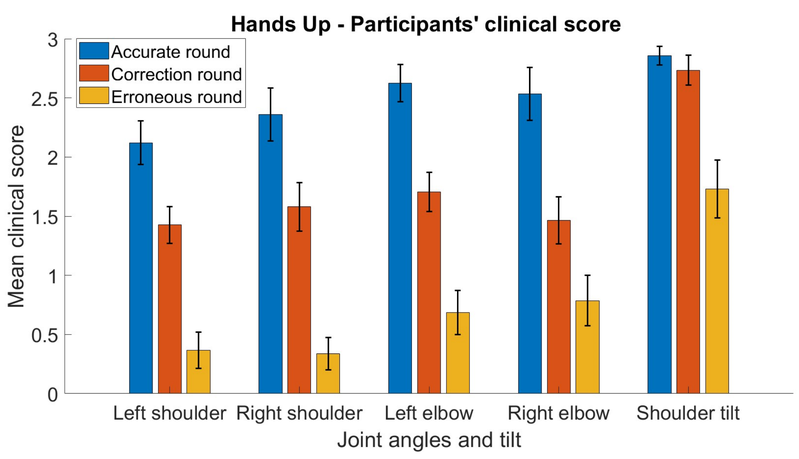
Movement: ✓ Correct, ✗ Incorrect

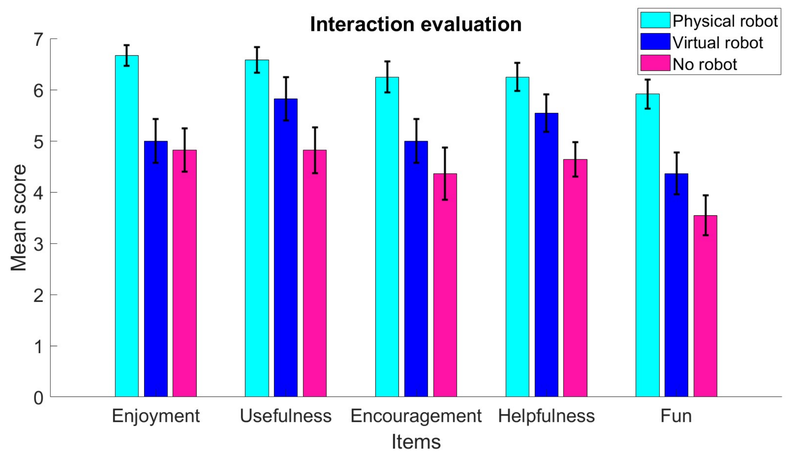
In 3 different **interaction modalities**:



Physical robot | Virtual robot | No robot

Results





1. MOVEMENT ASSESSMENT

The REHAB-PAL system accurately detected participants' kinematics and automatically generated correct movement scores.

2. INTERACTION EVALUATION

Participants' preference for the interaction with the physical robot, associated with highest levels of engagement and seen as the most effective mean of delivering exercise instructions.

3. SYSTEM EVALUATION

- ✓ Correct association of clinical labels
- ✓ Usefulness of customized feedback
- ✓ Valuable prioritization in feedback delivery
- ✓ Enhanced level of engagement

Conclusions

✓ Development of a **novel system** aimed at realizing **at-home** sessions of **rehabilitation** for **children with cerebral palsy** through the **assistance of the humanoid robot NAO**.

✓ The **REHAB-PAL system** simultaneously **trains** user's **motor abilities**, establishes **engaging interaction** through **customized feedback**, and provides **movement assessment**, which could be reviewed by physical therapists and parents.

✓ By testing the system with physical therapists and rehabilitation experts, **movement assessment worked properly**, **customized feedback** was considered **helpful**, and the interaction with **physical robot** was associated with **more engagement**.

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