

A pilot study of the impact of PedBotHome, a game-based, robot-assisted ankle therapy system, on adherence to a home exercise program by children with cerebral palsy

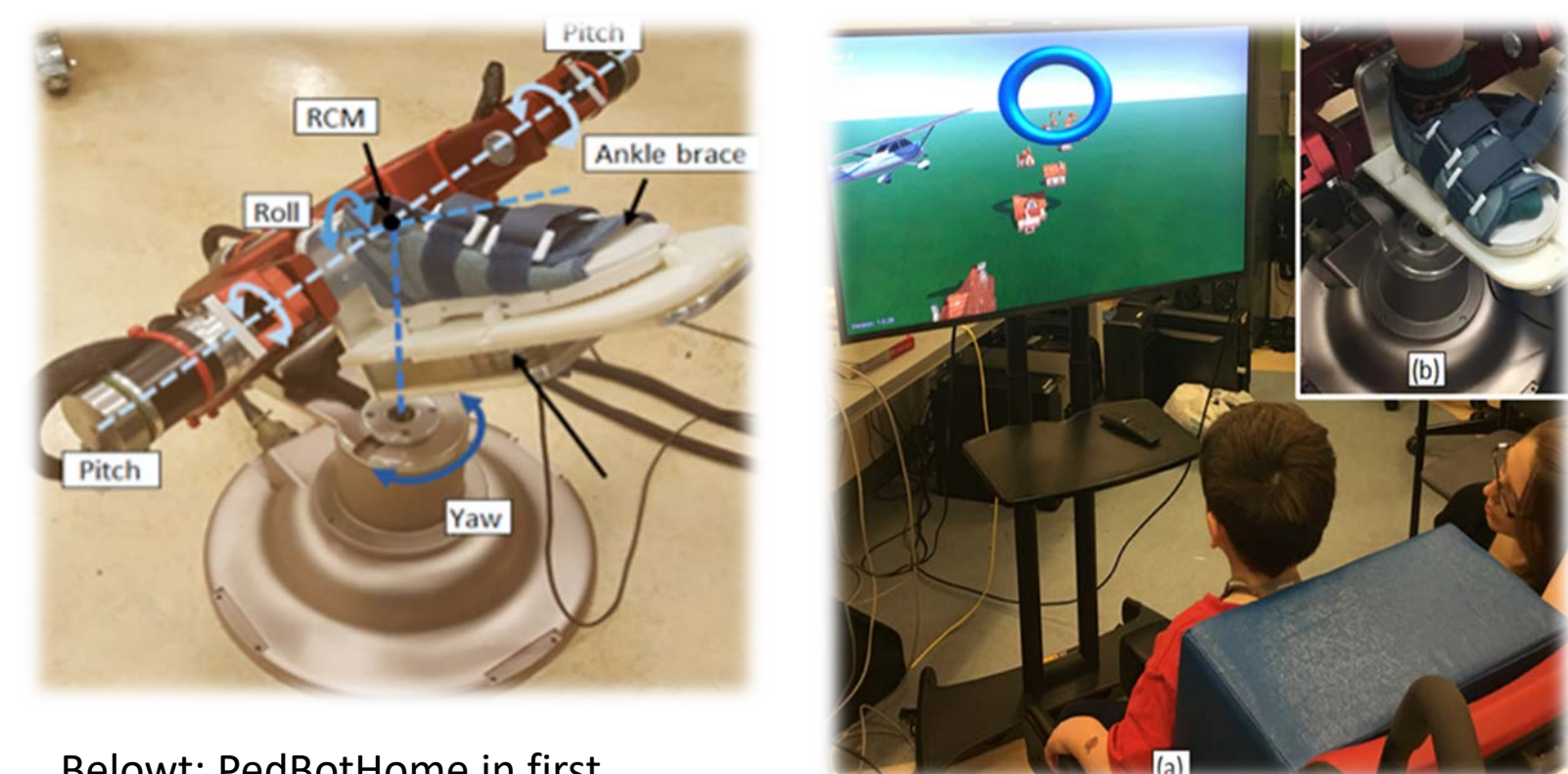
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Background & Problem: Cerebral palsy (CP) is the result of a static perinatal brain injury which causes deficits in motor skills. CP is the most common life-long physical disability occurring in childhood, affecting 2.3 to 3.6 per 1,000 school-age children. In the United States alone, 500,000 children under age 18 are affected by CP; in Europe, the affected population is even higher. Achieving an effective therapeutic dosage of ankle exercise for children with cerebral palsy (CP) can be difficult. Home exercise programs may extend therapy, however compliance is a barrier. Studies of home exercise adherence reveal many challenges. Exercise mediated by computer-based gaming and robot-assisted movement automates therapy and has been shown to increase engagement of children with CP.

Game-based, Robotic Ankle Therapy System: PedBotHome

Based on a robot (PedBot) for ankle rehabilitation we developed at our pediatric hospital, we created a lower cost robotic home device, similar to the lab version, that has 3 degrees of freedom and can be used in both active or assist/resist mode ankle therapy. The angular motion of the device is tracked by an Android cell phone attached underneath the foot plate. This cell phone communicates with the desktop computer via Wifi network and sends the angular positions of the robot. The child engages with the robot, moving his/her ankle, pitch, roll, or yaw, to pilot an airplane through a changing series of obstacles in a computer-based game.



Far left: Pedbot with 3 DOFs: pitch (dorsiflexion and plantarflexion), roll (eversion and inversion), and yaw (abduction and adduction). Near left: Child with cerebral palsy (a) playing airplane video game using PedBot as an input device (b). Note: All photograph used with consent of the parents and child

Below: PedBotHome in first child's home



Research Objective: To Explore whether PedBotHome, a therapist-supervised, game-based and robot-assisted ankle therapy system impacts adherence to a home exercise program

Design, Participants, Setting: Case series; 5 children with CP (10-16 years of age, 4 female), 4 parents (3 female); families' homes

Methods: Families piloted PedBotHome in their homes for 28 days. Child and parent interaction with the system was observed and video-recorded during the final week of the pilot

Follow-on, semi-structured interviews were conducted with participants in-home and audio-recorded. Audio materials were transcribed; transcripts, observation notes, and videos were imported to NVivo12 for analysis.

Research Question: How well does the experience of families using PedBotHome fit within existing explanatory frameworks for adherence to home exercise programs among families of children with CP?

Theories of Home Exercise Adherence in CP: Two theories, both developed using Grounded Theory methods, have been proposed to explain home exercise adherence in families of children with CP. Taylor et al., 2004 (Theory 1, figure 1) conducted in-depth interviews with 11 children (8-18 years) and their parents who implemented a home lower-extremity strengthening program. Lillo-Navarro et al., 2015 (Theory 2, figure 2) conducted six focus groups with 28 parents of younger children (6 months – 6 years) on their experience carrying out prescribed exercises at home. These two theories identify both concordant as well as divergent themes.

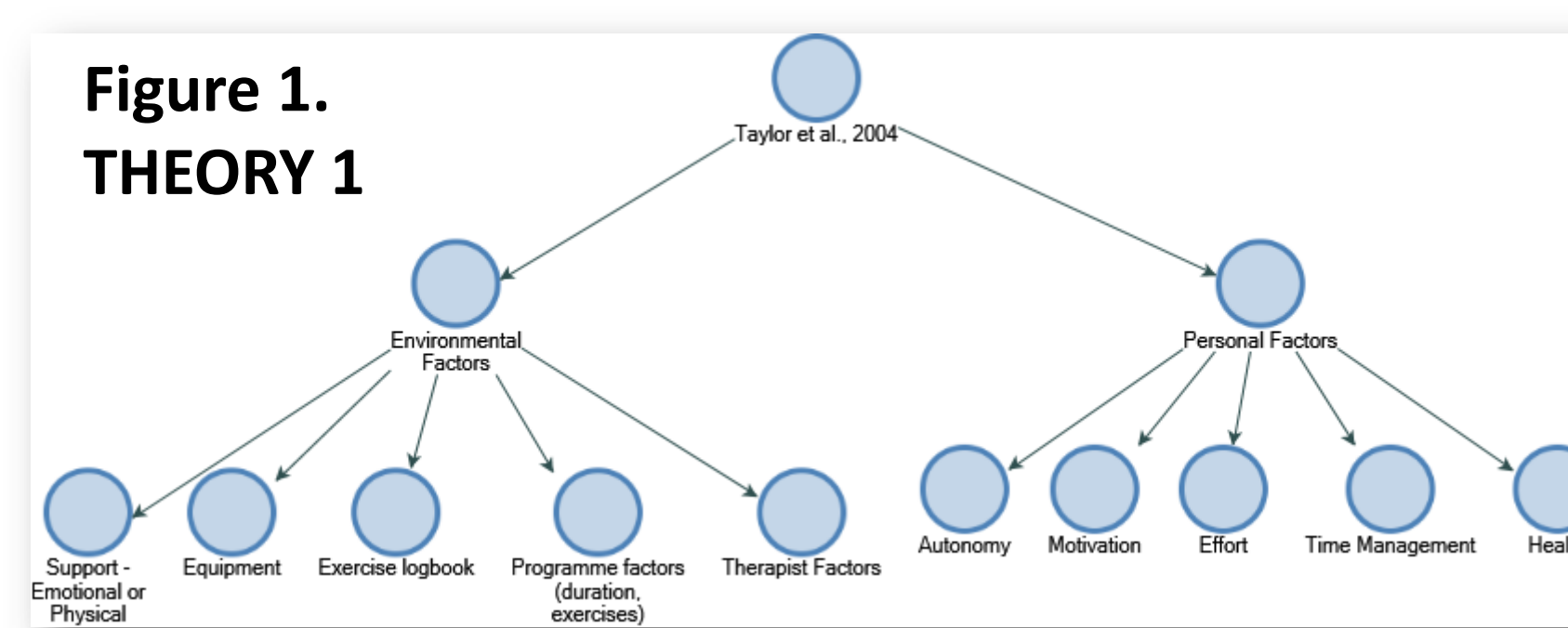
Procedure: We created a synthesis of the themes identified across Theories 1 and 2 and examined how observations and shared experiences of PedBotHome corresponded to them. Given the older age of our child sample, we extended theory 2 themes, originally derived from exclusively parental experience, to the child experience as well.

Results: Of 21 factors (table above) advanced to explain home exercise adherence in families of children with CP, 12 were relevant to our PedBotHome pilot participants, seven were not relevant, and two were variably relevant, subject to personal factors, such as maturity. All personal factors previously identified were observed to impact use of PedBotHome as well. Factors related to recordkeeping and correct execution of exercise were not relevant in

THEORY 1	THEORY 2	Adherence Factors (Synthesis)	Aligned PedBotHome Experience
Fit of Exercise Program in the Home Environment			
X		Exercise Equipment	Relevant. The equipment, PedBotHome, is focal.
X		Exercise Logbook	Not relevant. Exercise program, duration, performance maintained by the system.
X		What the Exercise Is	Relevant. Complaints esp around yaw (adduction/abduction) motion.
	X	Perceived Effectiveness of Exercise	Relevant. Enhanced enthusiasm for PedbotHome. Girls, 14 and 13, perceived improved performance in rock-climbing and ballet respectively..
	X	Fun Doing Exercise	Variable Relevance. Girl, age 10, very engaged in game, focused on beating her previous score. Older children found it became monotonous, but was more engaging than un-mediated exercising
	X	Comfort During Exercise	Relevant. Discomfort most frequent reason for change request, questions of malfunction.
	X	Perceived Complexity of Doing Exercise	Not Relevant. Exercises titrated by system, though therapist-initiated changes in resistance, speed of targets, increased the challenge of the game for the child..
X	X	Time Exercises Take to Complete	Variable Relevance. Older children alert to disparity between game time and clock time. Ten-year-old unaware..
X	X	Family Support or Disruption	Relevant: Parental work obligations frequent reason for missed sessions when child was not autonomous.
Therapist Support (Parent/Child Perspective)			
X	X	Demonstrating Exercises	Not relevant, apart from initial instructions for use. Program created by therapist, delivered by the PedBotHome system.
X	X	Coaching	Not Relevant. No perceived need for help with system setup or use.
	X	Perceived regular monitoring	Not Relevant. Participants largely unaware of/ disinterested in background monitoring of their performance
	X	Giving Reminders	Not Relevant. Adherence was 90%, but possible future enhancement
	X	Identifying changes in child's exercise performance	Relevant: Valued, though not directly from therapist. Functional both at the level of real-world performance improvement and performance on the PedBotHome game
	X	Providing Goal-based incentives	Relevant: Similar to weighting of the utility of identifying changes in child's exercise performance.
	X	Providing peace of mind	Not relevant. Note, children all older than the 6-mos to 6 year-olds in Lillo-Navarro sample, perhaps cause of greater parental ease.
Personal Factors (Child)			
X		Autonomy	Relevant. All children were able to set up and run PedBotHome without adult intervention. Some relied parental reminders to do their exercises.
X		Effort	Relevant: Misalignment of exercise with child's perceived need created frustration and disengagement
X		Health	Relevant: Episodes of illness caused gaps in program adherence
X		Motivation	Relevant: Game itself was motivating for the younger child. Personal discipline, sense of commitment was a driver among older children
X		Time Management	Relevant: A factor for older, more autonomous children with more intense school and extra-curricular commitments.

Results, Con't: PedBotHome. Factors related to on-going coaching and motivation from the therapist were not relevant, though the importance of the processes underlying them, such as the importance of both the child's and parent's perceptions of progress, remained.

Discussion: PedBotHome has the potential to mitigate some barriers to home exercise adherence identified in prior studies of programs without such robotic and gamified enhancement. Greatest gains may be in the areas of decreased family burden and demands on therapists' time, increasing efficiency and quality of delivered care. More study, particularly of difference across developmental levels, is needed.



Thematic Convergence and Divergence Across Two Theories of Home Exercise Adherence Among Families of Children With Cerebral Palsy

