Multimodal Technologies and Interaction

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Human–Robot Interactions: A Pilot Study of Psychoaffective and Cognitive Factors to Boost the Acceptance and Usability of Assistive Wearable Devices

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Abstract: Robotic technology to assist rehabilitation provides practical advantages compared with traditional rehabilitation treatments, but its efficacy is still disputed. This controversial effectiveness is due to different factors, including a lack of guidelines to adapt devices to users' individual needs. These needs include the specific clinical conditions of people with disabilities, as well as their psychological and cognitive profiles. This pilot study aims to investigate the relationships between psychological, cognitive, and robot-related factors playing a role in human–robot interaction to promote a human-centric approach in robotic rehabilitation. Ten able-bodied volunteers were assessed for their anxiety, experienced workload, cognitive reserve, and perceived exoskeleton usability before and after a task with a lower-limb exoskeleton (i.e., 10 m path walking for 10 trials). Pre-trial anxiety levels were higher than post-trial ones ($p < 0.01$). While trait anxiety levels were predictive of the experienced effort (Adjusted-$r^2 = 0.43$, $p = 0.02$), the state anxiety score was predictive of the perceived overall workload (Adjusted-$r^2 = 0.45$, $p = 0.02$). High–average cognitive reserve scores were predictive of the perception of exoskeleton usability (Adjusted-$r^2 = 0.45$, $p = 0.02$). A negative correlation emerged between the workload and the perception of personal identification with the exoskeleton ($r = -0.67$, p-value = 0.03). This study provides preliminary evidence of the impact of cognitive and psychoaffective factors on the perception of workload and overall device appreciation in exoskeleton training. It also suggests pragmatic measures such as familiarization time to reduce anxiety and end-user selection based on cognitive profiles. These assessments may provide guidance on the personalization of training.

Keywords: robotic rehabilitation; cognitive reserve; exoskeleton; anxiety; usability

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Academic Editors: Jan Auernhammer, Takumi Ohashi and Wei Liu

Received: 13 November 2024
Revised: 18 December 2024
Accepted: 22 December 2024
Published: 9 January 2025

Citation: Bertuccelli, M.; Tortora, S.; Trombin, E.; Negri, L.; Bisiacchi, P.; Menegatti, E.; Del Felice, A. Human–Robot Interactions: A Pilot Study of Psychoaffective and Cognitive Factors to Boost the Acceptance and Usability of Assistive Wearable Devices. *Multimodal Technol. Interact.* **2025**, *9*, 5. https://doi.org/10.3390/mti9010005

1. Introduction

Robotic technology for assistance and rehabilitation is an emerging field of research. This is due to the several advantages of robotic rehabilitation compared to conventional physiotherapy. The high-intensity and high-dosage training offered by robotic rehabilitation can enhance neuronal plasticity during the subacute phase following a brain injury [1–4]. As the user's disability improves, robotic therapy can be tailored to meet individual needs (e.g., progressively challenging motor performance) [5,6]. The sensors integrated into the exoskeletons can allow for the gathering of different performance measures [7]. Finally, the use of robotic devices for rehabilitation can unburden the clinical staff workload, optimizing resources.

Despite its potential, the efficacy of robotic rehabilitation is still disputed [8,9], and results are often inconclusive [8,10,11]. This controversial effectiveness is likely related to a variety of factors: the lack of shared clear-cut criteria to set the device parameters [8,9,12]; the physical features of most of the available devices (e.g., bulky, heavy, obtrusive) [13]; and the absence of selection criteria to identify people who would really benefit from this type of intervention. Among the factors currently considered when allocating people with motor impairments to robotic rehabilitation is their physical condition [14], but their cognitive and psychological profiles are neglected. A recent study showed that cognitive impairment is a negative predictor of functional and motor outcomes in people with stroke treated with upper-limb robotic therapy [15]. More generally, data from experimental and clinical research indicate that the response to motor rehabilitation is predicted by cognitive functioning, particularly attention, working memory, and visual spatial abilities [16]. Hence, it is relevant to assess a participant's cognitive profile and enhance their attention abilities before they undergo robotic rehabilitation [17,18].

Psychological factors including high anxiety levels [19], poor motivation [20], and psychoaffective conditions, which can surge in patients (e.g., post-stroke depression [21]), can have a detrimental impact on functional outcomes. Psychological characteristics, like anxiety and the perceived sense of control, can have a greater impact on the rehabilitation outcomes of people receiving robotic treatment than on those receiving traditional rehabilitation [19].

Anxiety levels, motivation, and the sense of control are also involved in the subjective perception of exoskeleton usability, which can affect its acceptance [22]. Usability is defined as the ability of an end user to perceive and use a system to accomplish goals successfully, efficiently, and pleasantly [22]. Usability perception boosts motivation and compliance and has a positive relationship with treatment outcome confidence and device acceptance [22,23]. Figure 1 summarizes all the factors mentioned above which are considered to play a role in achieving efficient human–robot integration.

The concept of human–robot interaction in rehabilitation is a relatively recent and broad research field: a human-centric approach is mandatory in robotic rehabilitation to direct the development of future devices, as well as the appropriate selection of end users [24]. These factors have never been jointly assessed in clinical trials with robotic devices for gait training. Furthermore, little is known about how these factors interact.

The current pilot study aims to inquire about the interactions between the factors considered to play a role in efficient human–robot integration during a task with a lower-limb exoskeleton involving a group of able-bodied volunteers. Specifically, the following relationships between factors are hypothesized and tested:

(I) Anxiety: anxiety levels can predict the experienced workload while using the exoskeleton (HP1) and the perceived exoskeleton usability (HP2).
(II) Cognitive reserve: cognitive reserve can predict the experienced workload (HP3) and the perceived exoskeleton usability (HP4).
(III) The physical performance (i.e., the total time spent donning the exoskeleton and the number of steps) can predict the experienced workload (HP5).
(IV) The experienced workload correlates negatively with the perceived exoskeleton usability (HP6).

By proving the above listed hypotheses, our ultimate goal is to demonstrate the necessity for robotic rehabilitation programs to be tailored to each individual's psychoaffective and cognitive characteristics.

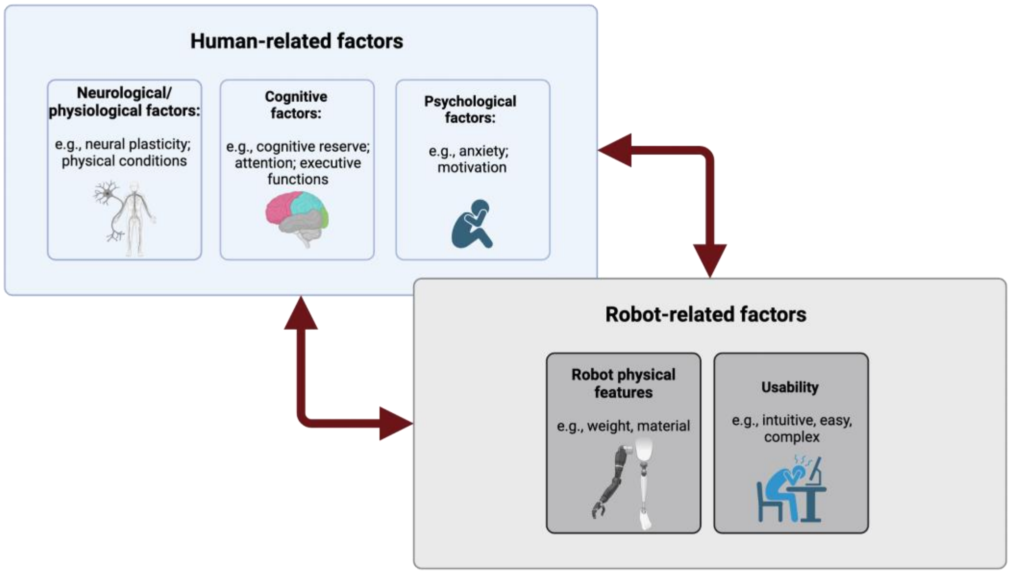

Figure 1. This figure outlines the factors considered to play a role in an efficient human–robot interaction. The blue boxes enclose factors related to human physical, cognitive, and affective characteristics. Robot-related factors are reported in the grey boxes and comprise robot physical features and perceived usability. The interactions between human- and robot-related factors determine the capability of a device to be integrated with the end user. This is a fundamental step to ensure rehabilitation effectiveness.

2. Materials and Methods

This was an observational pilot study conducted following the guidelines of the Declaration of Helsinki and approved by the Ethical Committee of the Psychology Department, University of Padua (code number: 217-b).

2.1. Participants

Ten healthy volunteers (five males) from Padova University took part in this study and provided written informed consent. Participants were considered eligible for inclusion if they were aged between 18 and 30 years, were naïve to exoskeleton use, and had anthropometric characteristics meeting exoskeleton requirements (i.e., height range: [150–180 cm]; weight < 90 Kg). The exclusion criteria were any neurological disease, motor disabilities, osteoporosis, history of fractures, and a confirmed diagnosis of anxiety disorder and/or cognitive disability. Table 1 reports the characteristics of the enrolled sample.

Table 1. Sample descriptive characteristics.

	Mean (SD)	Median (Min–Max)
Age (years)	24.4 (2.37)	25 [18–26]
Height (m)	1.68 (0.07)	1.68 [1.58–1.78]
Education (years)	18.4 (2.12)	18.5 [13–20]

2.2. Questionnaires

(1) State–Trait Anxiety Inventory (STAI-Y): State and trait anxiety were tested through the Italian version of the STAI-Y [25]. STAY-Y is a 40-item self-report and validated questionnaire whose scores range from 20 to 80, with higher scores indicating higher

levels of anxiety. The questionnaire assesses both trait anxiety (i.e., habitual subject proneness to anxiety) and state anxiety (i.e., current state of anxiety in relation to a specific event, which, in this case, was exoskeleton use).

(2) Cognitive Reserve Index questionnaire (CRIq): Participants' cognitive reserve was assessed by means of the CRIq [26], a semi-structured interview collecting information related to the participants' entire adult life. The questionnaire is divided into 3 sections respectively evaluating education, working activity, and leisure time.

(3) The NASA Task Load Index (NASA-TLX): The NASA-TLX was administered after the use of the exoskeleton to evaluate the task-related experienced workload [27]. This self-reported questionnaire is a multi-dimensional workload assessment tool evaluating six subscales of the workload: mental demand, physical demand, temporal demand, performance, effort, and frustration (see Supplementary Material Table S1 for scale definitions [27]). The questionnaire is tied to the performance of a task or to the use of a system and implies rating each dimension on a scale from 0 to 100.

(4) User experience questionnaire (AttrakDiff): Exoskeleton usability was evaluated through the AttrakDiff questionnaire (from https://attrakdiff.de/index-en.html, accessed on 18 December 2024). The AttrakDiff consists of 28 items, each one formed of bipolar 7-point semantic differential scales, composed of opposite words (e.g., "confusing" vs. "clear"). The questionnaire scores were converted to a scale ranging from +3 to −3, where the score 0, corresponding to a neutral evaluation of the exoskeleton, overlapped with a score of 4 on the Likert scale. The items were then grouped in the following factors: pragmatic quality (PQ): index of product usability and perceived level of user ease or difficulty in achieving a goal; hedonic quality—stimulation (HQ-S): how the product is perceived as interesting and stimulating in its contents, characteristics, and styles of interaction; hedonic quality—identity (HQ-I): index of the extent to which the product supports a social function and allows user identification; attractiveness (ATT): index of the total perceived value of the product based on its pragmatic and hedonic qualities.

2.3. The Exoskeleton: ALICE

We used an assistive lower-limb-controlled exoskeleton (ALICE) available at the Intelligent Autonomous System Laboratory (IAS-Lab) of the University of Padova (see Figure 2). ALICE, developed by the French company INDI Engineer and Design, is developed primarily with open-source parts and materials produced in aluminum or by 3D printing. The exoskeleton has four active joints (two hips and two knees) driven by brushed DC motors and a worm gearbox. Each actuation unit provides a maximum torque of 26 Nm and a nominal torque of about 10 Nm; the rated voltage is 12 V, and the power consumption is 120 W nominal and 260 W peak. Each joint is equipped with a linear encoder for measuring the joint position in real time. The low-level control unit (Arduino Mega 2650 R3, Arduino, Italy), the high-level control (Beelink SEi8, Intel® Core i5, 8 GB RAM, Beelink, Shenzhen, China), and the power supply are placed off board to reduce the overall weight worn by the subject and connected to the exoskeleton through a bundle of 15 m cables. The length of the links and the size of the pelvis frame were manually adjusted by an expert operator to fit the body characteristics of each participant. The exoskeleton gait profile was activated by participants by attempting a step with the desired leg. The exoskeleton then provided additional power complementing the user leg strength needed to complete the gait trajectory.

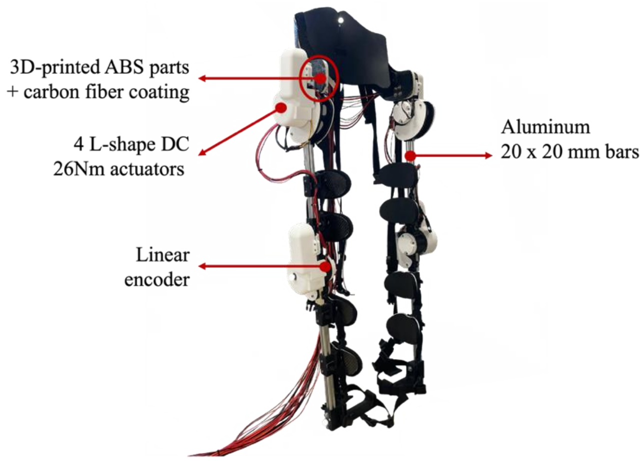

Figure 2. ALICE lower-limb exoskeleton. The picture represents the open-source, active lower-limb exoskeleton employed in the protocol and available at the IAS-LAB of Padova University.

2.4. Data Collection

Data were collected at the IAS-LAB of the University of Padova. Before donning the exoskeleton, participants answered the STAY-Y (i.e., state and trait anxiety scales) and CRIq questionnaires. Once they donned the exoskeleton, participants were instructed to walk and move around to familiarize themselves with it for 10 min. The control parameters of the exoskeleton were manually set by the operator during the familiarization phase based on participants' feedback. Participants were then asked to walk on a 10 m walkway at a self-selected speed for 10 trials while wearing the exoskeleton. The total time spent wearing the exoskeleton (including the between-trial intervals and familiarization phase) and the number of steps made during the trials were collected to objectively quantify effort and physical fatigue. At the end of the trials, participants were administered the state anxiety scale of the STAY-Y again, the NASA-TLX, and the AttrakDiff. See Figure 3 for a schematic representation of the data collection procedure.

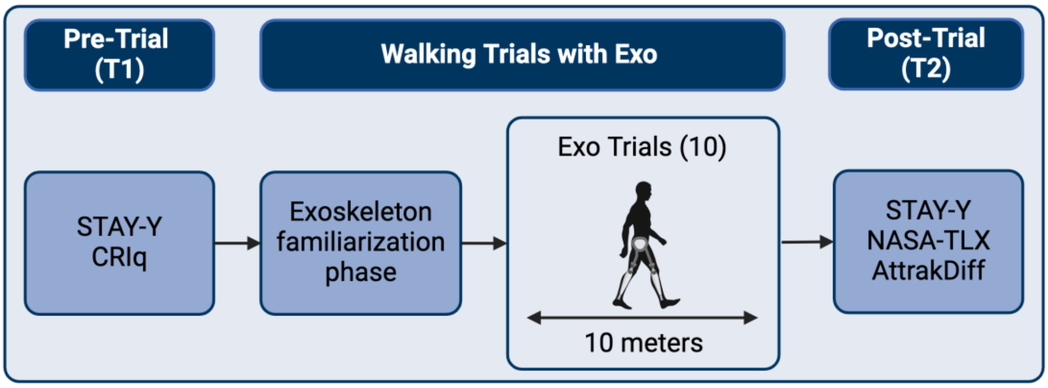

Figure 3. Schematic representation of the data collection process. Pre-trial (T1): before donning the exoskeleton. Post-trial (T2): after the execution of the ten walking trials with the exoskeleton.

2.5. Statistical Analysis

The statistical analysis was performed using RStudio software (Rstudio Team, 2015, Version 1.2.5001). Statistical significance was set at a p-value of <0.05. The data distribution was tested with a Shapiro–Wilk normality test. Within-group differences to evaluate state anxiety changes between pre and post exoskeleton trials and to compare questionnaire scores were evaluated with a paired sample t-test or a Wilcoxon signed-rank test based on the Shapiro–Wilk results. The hypothesized relationships between human-related and robot-related factors were tested through the Pearson correlation coefficient (r) and generalized linear models (GLMs). The participants' anxiety levels, cognitive reserve, and motor performance served as model explanatory variables, while the experienced workload (i.e., NASA-TLX) and perceived exoskeleton usability (i.e., AttrakDiff) served as predicted variables.

3. Results

3.1. STAY-Y

The Shapiro normality test revealed a normal distribution for the STAY-Y scores (trait anxiety scores: W = 0.96, *p*-value = 0.77; state anxiety scores: W = 0.95, *p*-value = 0.70). The mean trait anxiety of the sample was 40.10 ± 11.46, which was significantly higher than the state anxiety before trial execution (state anxiety pre-trial mean ± SD: 30.7 ± 5.94, *p*-value = 0.04). The state anxiety levels before the trial were significantly higher than the state anxiety levels post-trial (pre-trial mean ± SD: 30.7 ± 5.94, post-trial mean ± SD: 24.6 ± 4.69, *p*-value = 0.005). The Pearson correlation coefficient (r) showed no significant correlations between state anxiety levels, neither at T1 (r = 0.02, *p*-value = 0.96) nor at T2 (r = 0.46, *p*-value = 0.17), with trait anxiety.

3.2. Questionnaires and Motor Performance

Table 2 reports the mean and median scores related to the sample demographic characteristics; the scores in the CRIq, NASA-TLX, and AttrakDiff questionnaires; and the motor performance parameters.

Table 2. Descriptive statistics of questionnaire scores and motor performance after training. CRI_S: cognitive reserve index scholarity; CRI_W: cognitive reserve index working; CRI_FT: cognitive reserve index free time; CRI_TOT: cognitive reserve index total score; PQ: pragmatic quality; HQ_I: hedonic quality—identity; HQ_S: hedonic quality—stimulation; ATT: attractiveness.

Questionnaire	Subscale	Mean (SD)	Median (Min–Max)
CRIq	CRI_S	113.9 (27.79)	106 [84–160]
	CRI_W	96 (5.75)	96 [90–108]
	CRI_FT	95.9 (4.46)	95.5 [87–102]
	CRI_TOT	102.6 (10.63)	100.5 [84–121]
NASA-TLX	Mental demand	48 (26.16)	45 [20–80]
	Physical demand	48 (18.3)	45 [20–80]
	Temporal demand	28 (12)	30 [5–45]
	Performance	26.5 (11.32)	22.5 [15–45]
	Effort	62.5 (19.33)	62.5 [30–85]
	Frustration	33 (23.94)	27.5 [10–85]
	Total score	45.6 (15.86)	41.3 [25–72.67]
AttrakDiff	PQ	0.03 (0.74)	0.21 [−1.29–1]
	HQ_I	0.54 (1.19)	0.93 [−2–2]
	HQ_S	1.26 (0.82)	1.29 [−0.86–2.14]
	ATT	1.22 (0.76)	1.43 [−0.57–2.29]
	Total score	0.76 (0.72)	0.99 [−0.93–1.75]
Motor Performance	Total time (min)	32 (15.66)	29 [15–68]
	Number of steps	173 (18.77)	164 [156–210]

1. CRIq: Based on the questionnaire normative values (i.e., CRI normative classification: low ± 70; low–average = 70–84; average = 85–114; high–average = 115–130; high > 130) [26], seven out of the ten participants could be classified as having an

average CRI. Among the remaining, two participants had a high–average CRI and just one had a low–average CRI.

2. NASA-TLX: The Shapiro normality test revealed a non-normal distribution for at least one NASA-TLX subscale. Based on the NASA-TLX normative values [27], five of the ten participants rated the overall workload (i.e., total score) as pretty high (normative score range: 30–49), three as high (normative score range: 50–79), and two as average (normative score range: 10–29). Effort and mental and physical demand obtained the highest scores, with the effort scale having a significantly higher result than the mental (V = 42.5, p = 0.02) and physical ones (V = 50, p = 0.02).
3. AttrakDiff: The Shapiro normality test revealed a non-normal distribution for at least one AttrakDiff subscale. The overall hedonic dimension (i.e., HQ_S and HQ_I) had a significantly higher result than the perceived pragmatic quality (HQ mean $\pm$ SD: 0.9 $\pm$ 1.06; PQ mean $\pm$ SD: 0.03 $\pm$ 0.74, W = 160.5, p-value = 0.01). The graph in Figure 4 compares hedonic quality scores with pragmatic quality ones: despite the significant difference between hedonic and pragmatic quality, the overall judgment on the exoskeleton was neutral (figure created by https://www.attrakdiff.de/, accessed on 18 December 2024).

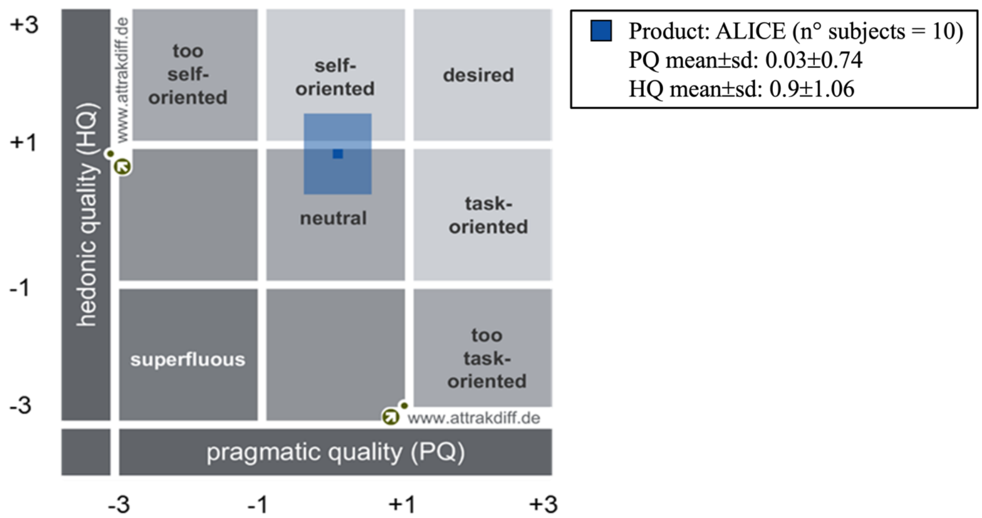

Figure 4. Outcome of the AttrakDiff questionnaire: hedonic vs. pragmatic quality. The blue square identifies the average value of perceived hedonic quality (y-axis) and pragmatic quality (x-axis). Based on the relation between these two scores, ALICE was evaluated as neutral.

3.3. Correlations and GLMs

The tested factor interactions as postulated in Section 1 (HP1-HP6) are shown schematically in Figure 5.

HP1: State anxiety levels after using the exoskeleton (T2) can predict the NASA-TLX total score (Adjusted r^2 = 0.45, F-statistic = 8.32, p-value = 0.02). None of the subscale scores of the NASA-TLX were predicted by the anxiety level, neither at T1 nor at T2 (see Supplementary Material, Table S2). The trait anxiety score can predict the perceived effort as assessed by NASA-TLX (Adjusted r^2 = 0.43, F-statistic = 7.71, p-value = 0.02).

HP2: None of the components of the AttrakDiff were predicted by the anxiety levels (see Supplementary Material, Table S3).

HP3 and HP4: The cognitive reserve index could not predict the scores of the NASA-TLX (see Supplementary Material Table S4) but was predictive of the perceived pragmatic quality on the AttrakDiff (Adjusted r^2 = 0.45, F-statistic = 8.52, p-value = 0.02).

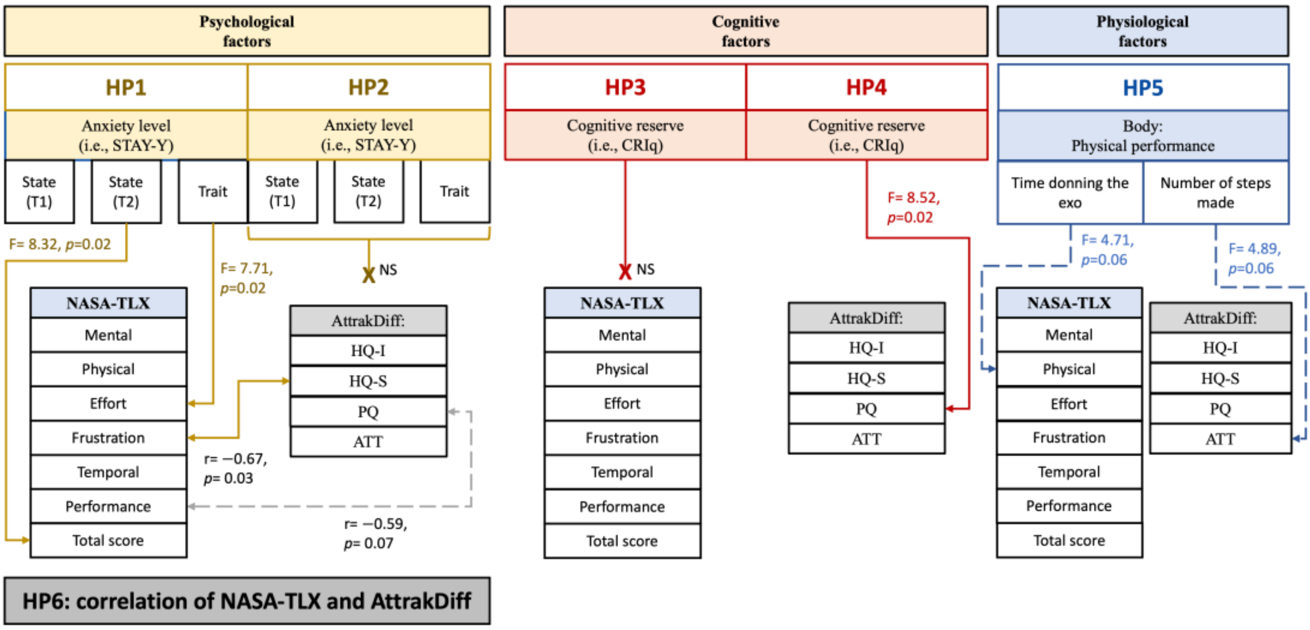

Figure 5. Model of factor interactions. This figure summarizes the tested hypotheses (HP1-HP6). We report the F-statistic values and *p*-values for the GLM analyses, and the correlation coefficients (r) and *p*-values for the correlation analyses. The significant relations are shown by solid lines, while the non-significant relations are denoted with "NS". The relationships that did not reach statistical significance but exhibited a tendency to do so are represented by dashed lines.

HP5: The motor performance was not predictive of the NASA-TLX score. However, there was a tendency of the total time spent donning the exoskeleton to predict the physical demand component of the NASA-TLX (Adjusted r^2: 0.29, F-statistic: 4.71, *p*-value = 0.06) and of the total number of steps to predict the reported exoskeleton attractiveness (Adjusted r^2: 0.30, F-statistic: 4.89, *p*-value = 0.06).

HP6: The Pearson correlation coefficient (r) showed a statistically significant negative correlation between the frustration subscale of the NASA-TLX and the HQ-S of the Attrakdiff (r = −0.67, *p*-value = 0.03).

4. Discussion

This study aimed to explore the interactions between the factors affecting human–robot interaction, with particular emphasis on the previously overlooked psychoaffective dimension. As a long-term perspective, we aimed to provide clinicians and end users with additional data to personalize and optimize the use of exoskeletons. The main findings for each investigated factor are discussed.

4.1. Psychological Factors

A first pragmatic indication emerging from our data is that users demonstrated high state anxiety levels before exoskeleton use, which decreased significantly after training. Additionally, the state anxiety before exoskeleton use was not correlated to the trait anxiety levels. These findings suggest that a lack of familiarization with or knowledge of the device induces unnecessary anxiety, which is not related to subjects' trait characteristics. Studies have proved that anxiety levels can contribute to poor treatment adherence and, consequently, to decreased rehabilitation efficacy [28]. Considering that even in a sample of young and healthy volunteers, the use of an exoskeleton can increase anxiety levels, it is of utmost importance to assess anxiety and keep it under control in people with disabilities requiring robotic rehabilitation.

The major concerns reported in the literature on the use of exoskeletons are observed in the elderly population and linked with the fear of dehumanization and loss of autonomy [19,29]. Thus, in at-risk populations, such as the elderly, anxiety should be reduced by providing preliminary information, ideally in the frame of informative meetings with the end user/patient or by allowing the participant to familiarize themselves with the device before training.

We hypothesized that anxiety levels could predict the overall workload experienced (HP1). Indeed, anxiety at T2 was predictive of the total NASA-TLX score. This is not surprising as participants were asked to answer the NASA-TLX questionnaire immediately after trial execution (T2). The state of anxiety at T2 could have influenced the judgment of the perceived workload rated at the same time. We confirmed previous results, as higher state anxiety levels have been associated with increased perceived workload [30]. Secondly, trait anxiety was predictive of the perceived effort. This is in line with theories postulating a role of trait anxiety in affecting task efficiency [31]: people with higher trait anxiety need to exert additional effort to execute a task efficiently. These findings prove that anxiety levels can influence the perception of task-related workload and effort.

On the contrary, no clear relations were found between anxiety levels and the AttrakDiff scores (HP2). Thus, at least in our sample, anxiety levels have no effect on the evaluation of the device. However, as hypothesized, we observed a correlation between AttrakDiff and NASA-TLX scores (HP6). In particular, a negative correlation emerged between the experienced frustration while using the exoskeleton and the rated hedonic quality (stimulation component). This means that those people finding the device more stimulating/challenging tended to experience less frustration while using it.

4.2. Cognitive Factors

The cognitive reserve index in our sample was mainly influenced by the education component. Indeed, most participants were young university students with almost no working experience. Contrary to our hypothesis (HP3), the cognitive reserve was not related to the perceived workload but was instead associated with the device evaluation (HP4). In particular, higher scores in the pragmatic quality of the exoskeleton (i.e., device functionality and accessibility) were associated with a lower cognitive reserve index. More specifically, analyzing the single scores of those with higher CRI, we observed that lower scores were attributed to the items indicating high device complexity and technology, while higher scores were given to the dimensions of motivation and challenge. This means that people with higher CRI can probably better understand the device's functionalities, perceiving it as less complex than those with lower CRI. At the same time, higher CRI is associated with higher motivation in using the device. It is thus plausible that people with higher education levels can be more motivated and less intimidated in undergoing robotic rehabilitation. In clinical populations requiring robotic rehabilitation, the evaluation of CRI can have a dual purpose: firstly, to assess the general cognitive status, which is generally associated with any rehabilitation treatment's efficacy [32,33], and, secondly, to identify those people having a higher probability of benefiting from robotic training.

4.3. Physiological Factors

Given the exploratory nature of this study, and the healthy population sample, the only considered physiological-related variables were those quantifying motor performance: the time spent donning the exoskeleton and the number of steps made with it. No significant relationships were found between the motor performance, the experienced workload, and AttrakDiff scores. However, tendencies were observed in line with our a priori hypothesis (HP5). First, there was a tendency of the total time spent donning the exoskeleton to predict the physical effort reported. This is reasonable considering that participants had to stand up for entire trial duration. Reducing the total time required to don and doff the exoskeleton could be a strategy to reduce end users' fatigue as they undergo robotic rehabilitation. The physical attributes of the exoskeleton are also a key factor: ALICE is considered lightweight in comparison to most exoskeletons used in rehabilitation settings (i.e., 30–40 kg), weighing approximately 12 kg. Despite its lighter weight, it may still exert a notable impact on individuals with lower body mass. A descriptive sub-analysis of the female participants showed that they reported higher physical effort scores (NASA-TLX subitem) than the male participants (mean score for females: 49 $\pm$ 16.7; mean score for males: 47 $\pm$ 21.7). Therefore, it is important to take both the exoskeleton's design and the user's physical characteristics into account when tailoring rehabilitation protocols.

Second, the total number of steps seems to be related to the perceived device attractiveness. The total number of steps is a more reliable parameter to assess the effective time of device use, as the total time spent wearing the exoskeleton also includes the between-trial intervals. These data indicate that longer use of a device can be a factor increasing its acceptance, which is in line with previous data [34]. If this is true, clinicians should consider the possibility of a gradual integration between device and patient as a function of the time spent using it.

4.4. Limitations

This study has a few limitations: The first is the small sample size. In fact, this was a pilot study, and its results need to be confirmed by testing a larger sample. The small sample size of our study limits both the generalizability of the findings and the statistical power. However, the results reflect the pilot nature of the study. Indeed, they aim to open further research on the topic and provide an experimental framework for future investigations.

The second is the sample characteristics: we enrolled a group of young, healthy individuals who willingly participated in the study. This may have created a bias in favor of an overall favorable assessment of exoskeletons or, at the very least, increased interest in the experiment. Additionally, the results of CRIq, which mostly reflect years of education, can be explained by the young age of our sample. Thus, future studies should extend these evaluations to elderly or disabled people, which are the real target of these exoskeletons.

However, this does not weaken our conclusions, as we wanted to demonstrate the presence of specific relationships between the variables thought to be important in human–robot interaction, which should be valid regardless of the sample characteristics.

5. Conclusions

This pilot study provides preliminary evidence of the impact of cognitive and psychoaffective traits on the perceived workload and device evaluation during exoskeleton training. In clinical practice, as well as in the scientific community, these crucial aspects have been mostly neglected despite their role in efficient human–robot integration. Assessing these factors jointly and considering their reciprocal interactions can help to develop a human-centric approach in robotic rehabilitation, which will guide the design of upcoming devices and end user selection.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/mti9010005/s1: Table S1: NASA-TLX subscales; Table S2: GLM results (HP1); Table S3: GLM results (HP2); Table S4: GLM results (HP3 and HP4).

Author Contributions: Conceptualization: M.B., S.T., E.M. and A.D.F. Recruitment: L.N. Software and data analysis: M.B., E.T. and S.T. Data collection: E.T., L.N. and S.T. Supervision: P.B., E.M. and A.D.F. Original draft preparation: M.B., S.T. and A.D.F. All authors critically discussed the results. All authors have read and agreed to the published version of the manuscript.

Funding: M.B., E.T., and A.D.F. received funding from AGE-It, PE8 Spoke 9, Italian PNRR (Piano Nazionale di Ripresa e Resilienza) funding scheme [DM 1557 11.10.2022]; A.D.F. received funding from PRIN 2022 (Fondo per il Programma Nazionale di Ricerca e Progetti di Rilevante Interesse Nazionale, 2022YPK5YB).

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Department of General Psychology of Padova University (code: 217-b, date of approval: 24 October 2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study. Written informed consent was obtained from the participants to publish this paper.

Data Availability Statement: The datasets generated and/or analyzed during the current study are not publicly available due to the participants' privacy. Anonymous data and code will be made available upon request to the corresponding author. The experiment was not pre-registered.

Acknowledgments: We acknowledge funding from Next Generation EU, in the context of the National Recovery and Resilience Plan, Investment PE8—Project Age-It: "Ageing Well in an Ageing Society" [DM 1557 11.10.2022]. The views and opinions expressed are only those of the authors and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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