Wireless Brain-Robot Interface: User Perception and Performance Assessment of Spinal Cord Injury Patients

Supplementary material: *report of Statistical Analysis*

Methods

Demographics

Initially, we planned comparisons of demographic data (e.g. age, education level) between groups. The variable age was compared between groups (healthy, patients) after testing for normality assumption. Normality was explored using visual inspection of histograms, normal Q-Q plots and boxplots, in terms of skewness and kurtosis [1–3]as well as using the normality tests (Shapiro-Wilk test and Kolmogorov-Smirnov Test) [4,5]. Since the age was approximately normally distributed for both groups, independent samples t-test was performed to reveal any significant age difference between groups as well as the mean and the standard deviation (SD) were calculated for each group. The pool of participants was assessed regarding their education level using the ranking: basic studies, pre-graduate level, graduate level, post-graduate level, PhD holders. Thus, we performed comparisons between groups regarding the education level using Mann Whitney (U) test our data are ordinal (Likert-type)[6].

Somatometric data

Somatometric data such as the height, the weight and the Body Mass Index (BMI) were also collected. Therefore, we planned comparisons of somatometric data between groups after testing for normality assumption using the aforementioned methodology. As the somatometric data were approximately normally distributed, all comparisons between groups were performed using independent samples t-tests.

Clinical evaluation

Medical history data and neurological data were analyzed via descriptive statistical methods. Moreover, we explored whether the smoking status is independent of the group or not using chi-square test. Scores resulted from neurological screening and psychometrics were tested for normality in order to compute proper measures of centrality and variation and define the between groups methods of comparison. Additionally, we planned comparisons of VVIQ's and its subcategories' scores between patients depending on their recovery as assess by ASIA classification. Questionnaire scores were tested for normality assumption between patients with negative outcome (ASIA-A, ASIA-B and ASIA-C) and patients with positive outcome (ASIA-D and ASIA-E) and as normality was met for both outcomes independent samples t-tests were performed.

BCI performance

Total scores of BCI performance in right and left hand as well as in both hands and training capacity were analyzed between groups. Initially, scores of both BCI and training performance were explored for normality between groups and since they were approximately normally distributed independent samples t-tests were used. Moreover, BCI scores were explored in patient group after grouping by ASIA classification. In more detail, BCI and training scores were tested for normality between patients with negative outcome (ASIA-A, ASIA-B and ASIA-C) and patients with positive outcome (ASIA-D and ASIA-E). Group differences investigated using independent samples t-test for BCI scores and Mann Whitney U tests for the training scores. We further explored differences in BCI and training scores between different neurological levels of injury (cervical, thoracic) after testing for normality. Since BCI and training scores reached approximately normality, they analyzed via independent samples t-tests. Additionally, linear regression analysis was used to investigate any association between BCI scores and NLI.

Possible correlations between BCI performance and age and BCI performance and psychometrics (VVIQ, BDI, and Rosenberg Self-Esteem Scale) were explored across groups (healthy, patients). The association between BCI performance and age was investigated for both groups using Pearson correlation coefficient since the involved variables were approximately normally distributed for both groups. Pearson correlation coefficient was also used for correlations BCI scores-VVIQ (total, 2, 4), BCI scores – Rosenberg whereas Spearman's coefficient was calculated in order to explore the associations BCI performance –VVIQ (1,3) and BCI performance and BDI as VVIQ(1,3) and BDI were not approximately normally distributed for both groups.

Godspeed Questionnaire

The scores of Godspeed sub-categories (Anthropomorphism, Animosity, Likeability, Perceived Intelligence, and Perceived Safety) as well as Godspeed total score were analyzed between groups and outcome (positive, negative) respectively. All scores have been tested for normality assumption following Shapiro-Wilk Test and using group and outcome respectively as grouping factor. All Godspeed scores apart from Godspeed-Perceived Safety met normality assumption. Therefore, group differences were explored using independent samples t-tests for all Godspeed scores except for Godspeed-Perceived Safety. Group differences in Godspeed-Perceived Safety were investigated using Mann Whitney U test. The aforementioned analysis scheme was identical for between group differences using as grouping factor group (healthy, patients) and outcome (positive, negative) respectively. Finally, possible correlations were explored between Godspeed's scores and BCI performance as well as Godspeed's scores and VVIQ scores. Pearson correlation coefficient and Spearman's coefficient were used depending on the normality assumption of the involved variables.

Results

Demographics

A Shapiro-Wilk's test ($p>0.05$)[4,5] and a visual inspection of histograms, normal Q-Q plots and boxplots showed that age was approximately normally distributed for both groups with a skewness of 0.407 (SE=0.687) and a kurtosis of -1.418 (SE=1.334) for healthy group and a skewness of 0.651 (SE=0.687) and a kurtosis of -0.752 (SE=1.334) for patient group. Planned comparisons of age between groups did not reveal any significant difference. Mean and standard deviation (SD) for each group were calculated and described in Table 1.

Groups	**Age Mean (SD)**
Healthy	46.2 (18.27)
Patients	45.0 (17.04)

Table 1: Descriptive statistics of age for both groups (healthy, patient).

Based on the performed analysis regarding the education level between groups, it did not emerge any statistically significant difference between groups (U=33.50, p=0.179) (Figure 1).

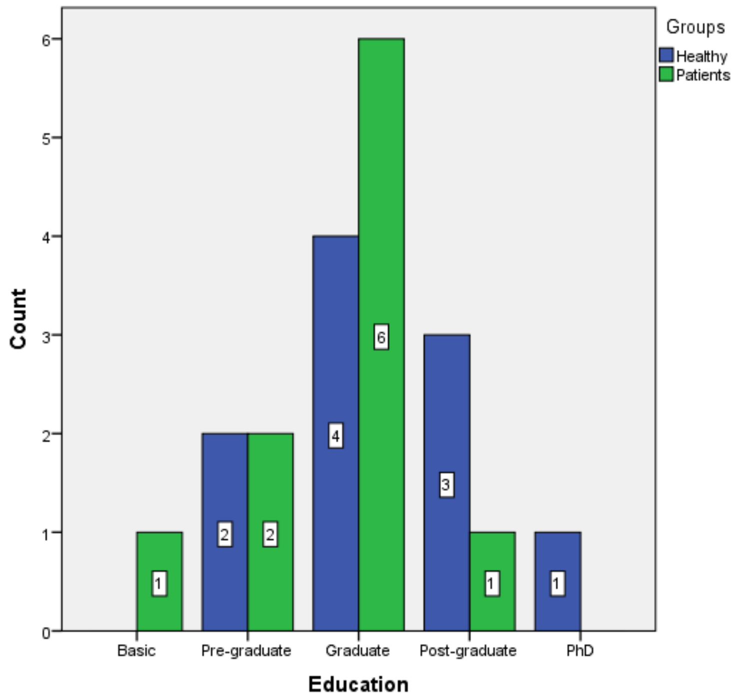

Figure 1: The education level of the healthy and patient participants.

Somatometric data

The variables height, weight and BMI were found to be approximately normally distributed based on a Shapiro-Wilk's test (p>0.05), visual inspection of normality graphs as well as in terms of skewness and kurtosis (Height – Healthy: skewness=-0.231 (SE=0.687); kurtosis=-1.029 (SE=1.334), Patients: skewness=0.078 (SE=0.687); kurtosis=-0.768 (SE=1.334), Weight–Healthy: skewness=0.302 (SE=0.687), kurtosis=-0.935 (SE=1.344), Patients: skewness=0.793 (SE=0.687), kurtosis=0.448 (SE=1.344), BMI – Height: skewness=0.374 (SE=0.687); kurtosis=-0.854 (SE=1.344), Patients: skewness=1.094 (SE=0.687); kurtosis=1.105 (SE=1.344)). Group differences in somatometric data was not revealed (Height: t=1.634, df=18, p=0.120; Weight: t=1.177, df=18, p=0.254; BMI: t=0.646, df=18, p=0.526). Depending on BMI scores, different

BMI categories were used (BMI: Underweight <18.5, Normal weight =18.5-24.9, Overweight=25-29.9, Obesity≥30). For both groups, the frequency of each BMI category was calculated (Figure 2).

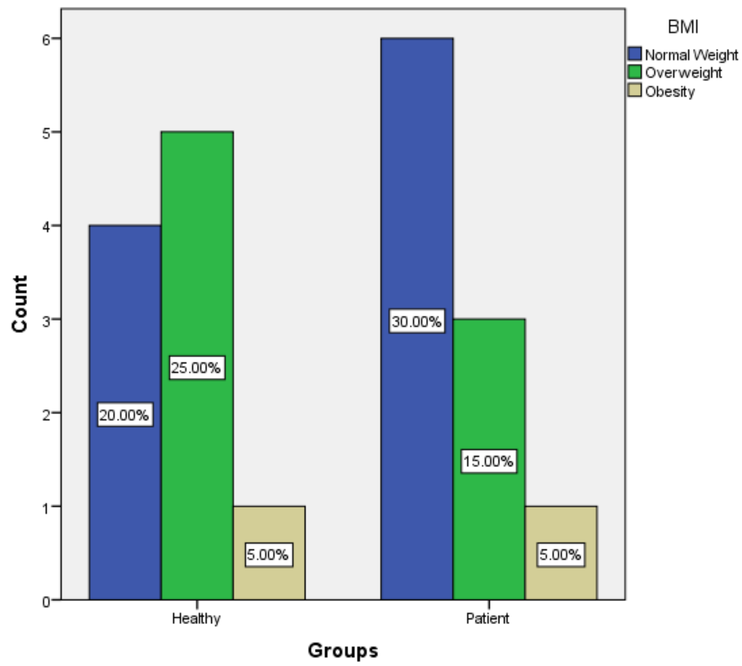

Figure 2: BMI categories across groups (the percentage of participants in each category is displayed on the bars).

Clinical data

Medical history taking led to data collection consisted of injury-related information for patient groups as well as neurological data and smoking status for both groups. Injury-related information consisted of age at injury, weight at injury and cause of injury. Two out of ten patients reported that injury happened at the age of 21 years whereas the remaining group participants gave different responses (Figure 3). The weight of the patients at injury is described in the following table (Table 2).

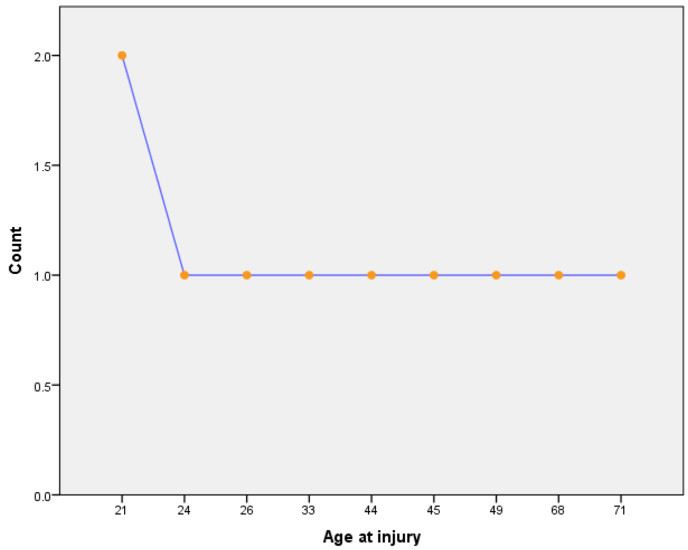

Figure 3: Patients' age at injury.

Code	Weight at Injury
CSI-02-001	62
CSI-02-002	97
CSI-03-001	87
CSI-02-003	80
CSI-02-004	58
CSI-02-005	81
CSI-02-006	75
CSI-02-007	70
CSI-03-002	53
CSI-03-003	67

Table 2: Patients' weight at injury.

Regarding the cause of injury, in 60% (6/10) of patients injury was caused by motor-vehicle accident, in 30% of participants was induced by fall from heights whereas for the remaining patients (10%) injury was caused by other factors apart from accidents and falls (Figure 4).

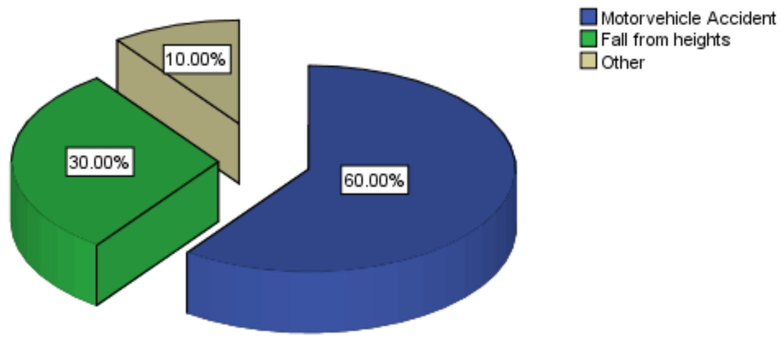

Figure 4: Reported causes of injury

Grouping causes of injury reported by age we found that most of the injuries (4/10) happened when patients were between 26.0-33.0 years old. The second more vulnerable age range to injuries (motor-vehicle accidents) seems to the age range 50.0-57.0 years old (Figure 5). Additionally, we should note that other causes of injuries were found to be more dominant in ages higher than 58 years old.

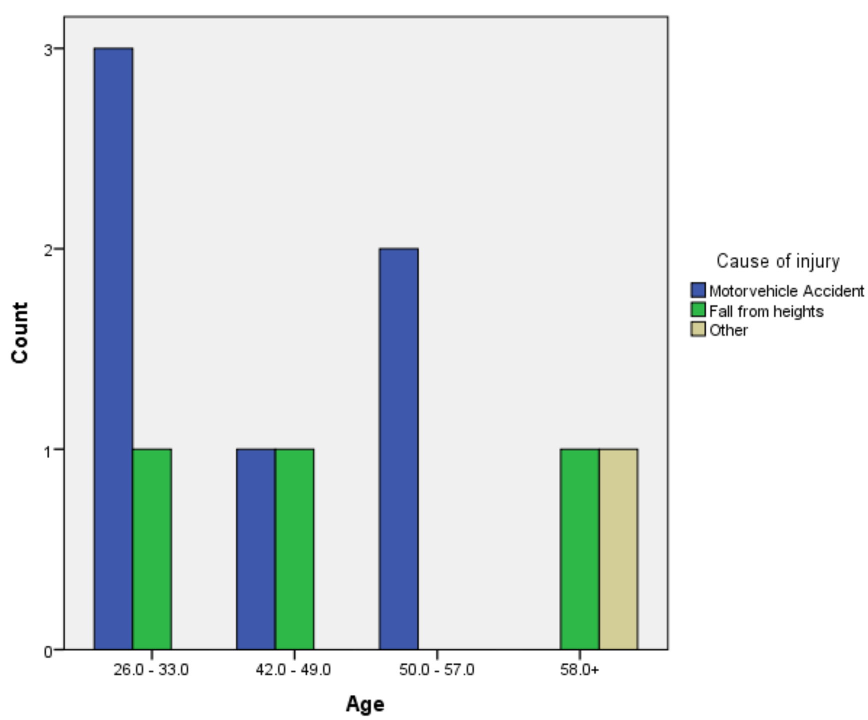

Figure 5: Grouping the reported cause of injury by patients' age.

With regards to injury severity, most of the patients were characterized as ASIA - D (40% of patients) whereas only one out of 10 patients was assessed as ASIA – A and ASIA – C respectively. Similarly, equal proportions of participants (20%) were evaluated as ASIA – B and ASIA – E respectively (Figure 6).

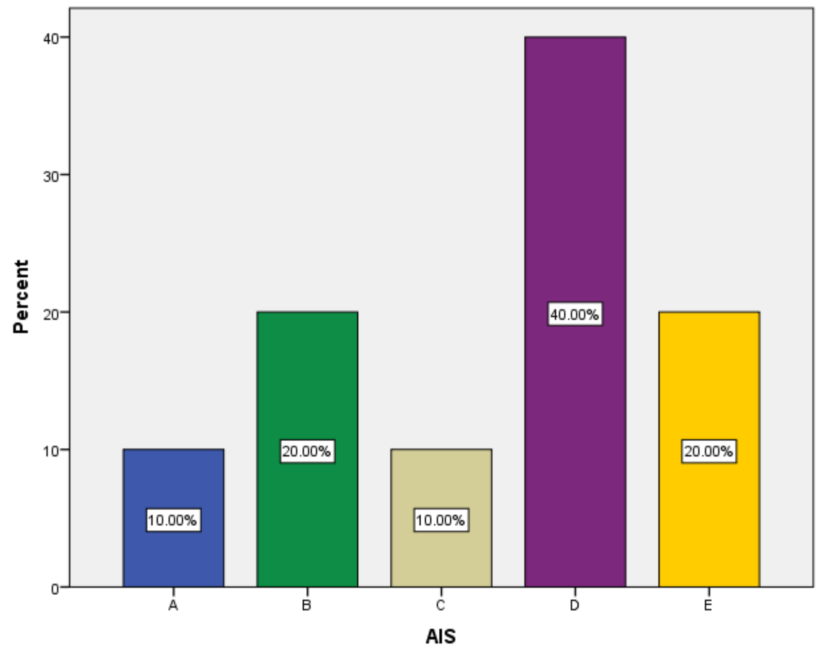

Figure 6: Patients' injury severity as assessed by ASIA Impairment Scale.

Moreover, the 70% of injuries reported were cervical whereas the remaining 30% were thoracic injuries. In more detail, cervical injuries have been reported in central brain sites (C4, C5, C6, C8) in 20%, 30%, 10% and 10% of patients respectively whereas temporal injuries have found in two out of ten patients (20%) in T4 site and in one out of ten (10%) in T7 site (Figure 7).

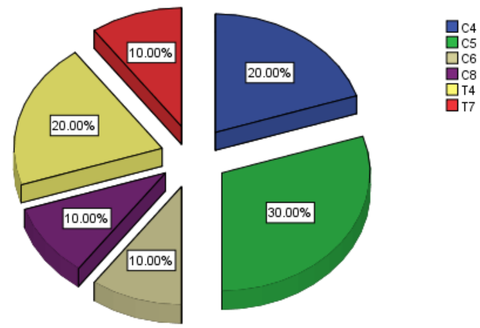

Figure 7: Neurological level of patients' injuries

Based on neurological assessment, the 50% of patients showed approximately intact general motor capacity (3/10 of patients scored 100 while 2/10 scored 98) and excellent both upper and lower extremities motor skills (3/10 of patients scored 50 in both categories whereas as 2/10 scored 48 in UEMS and 50 in LEMS). The remaining participants of the patient groups showed motor deficits (Table 3). With regards to sensory skills, the patients who preserved their motor skills (50%) scored as high as the healthy participants in light touch task (LT) and pinprick (PP) task (Table 3). Additionally, the median and the interquartile range (IQR) were calculated as measures of centrality and variation respectively (Table 3) because scores were not approximately normally distributed.

Code	Motor-Total	UEMS	LEMS	Sensory-Total	LT	PP
CSI-02-001	48	24	24	224	112	112
CSI-02-002	84	39	45	183	94	89
CSI-03-001	56	50	6	121	58	63
CSI-02-003	98	48	50	224	112	112
CSI-02-004	98	48	50	223	111	112
CSI-02-005	100	50	50	224	112	112
CSI-02-006	100	50	50	222	111	111
CSI-02-007	100	50	50	224	112	112
CSI-03-002	50	50	0	156	78	78
CSI-03-003	54	50	4	156	78	78
Median	91.0	50.0	47.5	222.50	111.0	111.50
Interquartile Range	47.0	4.3	44.5	68.0	34.0	34.0

Table 3: Neurological evaluation scores of the patient group.

Similarly, the 50% of patients who showed unimpaired motor and sensory skills scored as high as the healthy participants in g-SCIM-III test and its subcategories. In the remaining group, deviation in the performance at the g-SCIM-III test was found. The median has been computed as centrality measure and displayed in Figure 8 for both groups as scores at tests were not approximately normally distributed (g-SCIM-III-Total: Healthy (median= 100.0, IQR=0.0); Patients (median= 94.0, IQR= 51.3), g-SCIM-III-SC: Healthy (median= 20.0, IQR=0.0); Patients (median= 18.0, IQR= 7.3), g-SCIM-III-BS: Healthy (median=40.0, IQR=0.0); Patients (median=40.0, IQR=19.3), g-SCIM-III-M: Healthy (median=40.0, IQR=0.0); Patients (median=37.5, IQR=24.3).

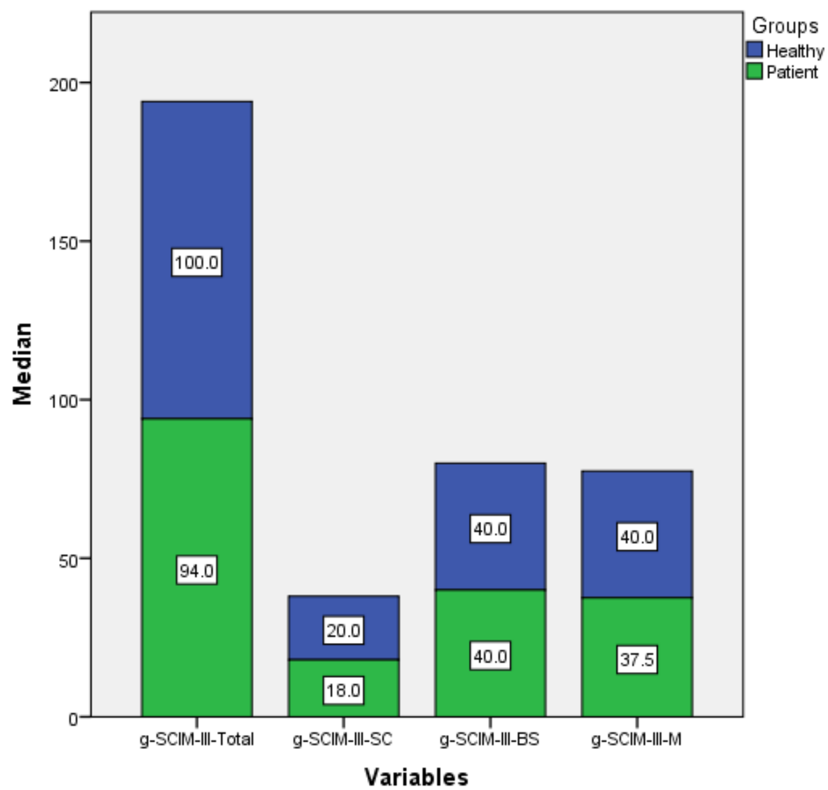

Figure 8: Median scores of both groups at g-SCIM-III test and its subcategories.

Exploring whether the smoking status is independent of the group or not, we observed a significant association (χ^2=5.051, df=1, p=0.025) (Figure 9).

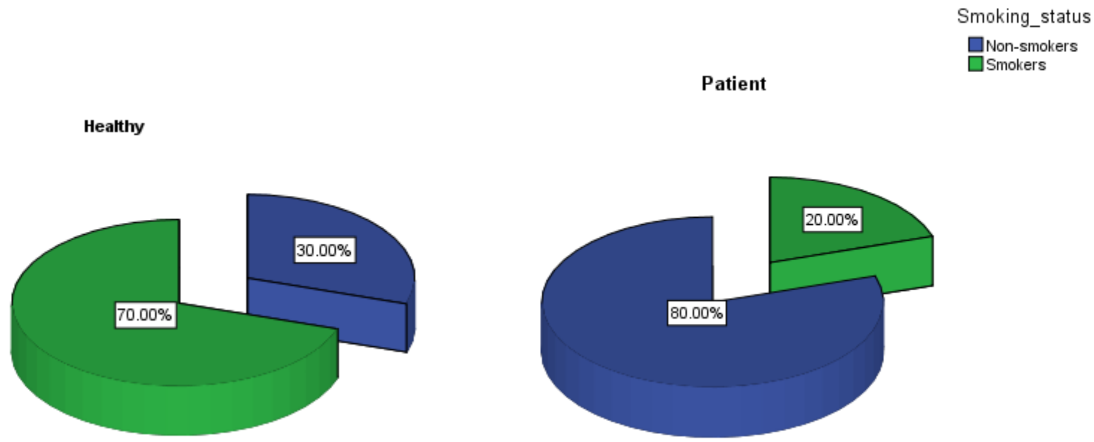

Figure 9: Smoking status of both healthy and patient group.

All participants answered in three psychometric questionnaires (VVIQ, Beck Depression Inventory (BDI) and Rosenberg Self-Esteem scale). Tests after scoring were analyzed between groups after exploring whether data was approximately normally distributed or not. Since normality assumption was not met for both groups in all VVIQ categories, Mann Whitney U test was performed for VVIQ1 and VVIQ3 while interdependent samples t-tests were performed for VVIQ total, VVIQ2 and VVIQ4.However, significant outcomes did not revealed (VVIQ: t=0.316, df=18, p=0.755; VVIQ1: U=42.0, p=0.533; VVQ2:t=-0.591, df=18, p=0.562; VVIQ3: U=29.50; p=0.113; VVIQ4: t=-0.236, df=18, p=0.816). However, patient group scored lower than healthy (Figure 10) but differences did not reach statistical significance (VVIQ: Healthy: 67.0(10.92); Patients 65.70(7.04), VVIQ1: Healthy (median=18.5, IQR=4.5); Patients (median=16.5, IQR=4.0), VVIQ2: Healthy 16.50(2.99); Patients 17.20(2.25); VVIQ3: Healthy (median=19.5, IQR=3.3); Patients (median=17.0, IQR=4.5), VVIQ4: Healthy 14.70(3.59); Patients 15.10(3.98)).Furthermore, we compared scores of VVIQ questionnaire and its subcategories between patients depending on their recovery as evaluated by ASIA classification (positive outcome, negative outcome). No considerable group differences were revealed in VVIQs scores (VVIQ: t=-1.094, df=8, p=0.306; VVIQ1: t=0.245, df=8, p=0.813; VVIQ2: t=-1.884, df=8, p=0.096; VVIQ3: t=0.086, df=8, p=0.934; VVIQ4: t=-1.233, df=8, p=0.253). Mean scores of both groups of patients are displayed in Figure 11).

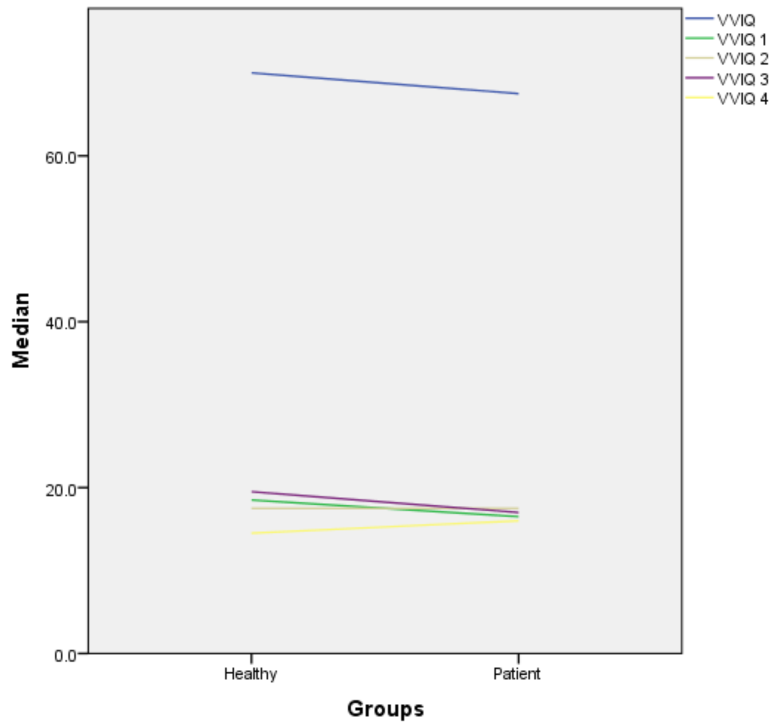

Figure 10: Performance of both groups at VVIQ test and its subcategories

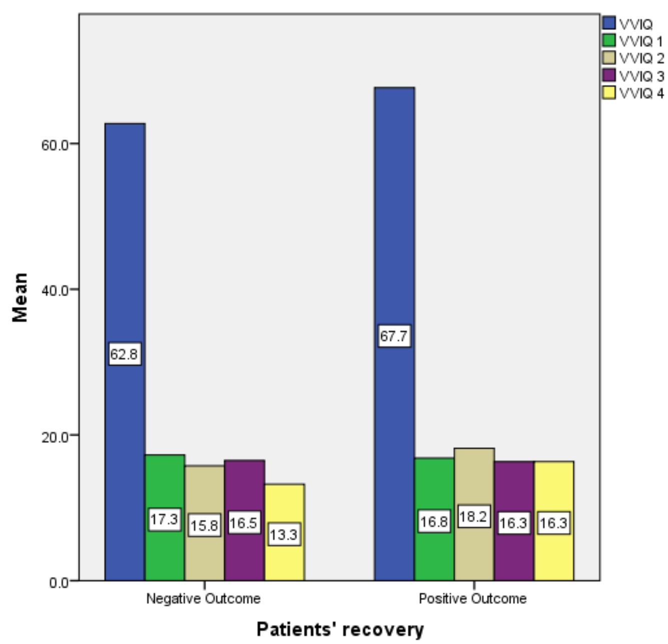

Figure 11: Scores at VVIQ questionnaire and its subcategories of both groups of patients.

BDI scores were not approximately normally distributed and thus, group differences were explored using non-parametric methods (Mann Whitney U Test). Scores at Rosenberg Self-Esteem scale met normality for both groups and therefore, independent samples t-test was performed. Even though, patient group showed increased depressive scores (BDI: Healthy (median=3.0, IQR=5.5); Patients (median=14.5, IQR=12.5)) and decreased self-esteem compared to healthy (Rosenberg (mean(SD)) – Healthy: 24.70(4.14); Patients 21.40(3.86)) (Figure 12), group differences were not statistically significant (BDI: U=26.0, p=0.069, Rosenberg: t=1.843, df=18, p=0.082).

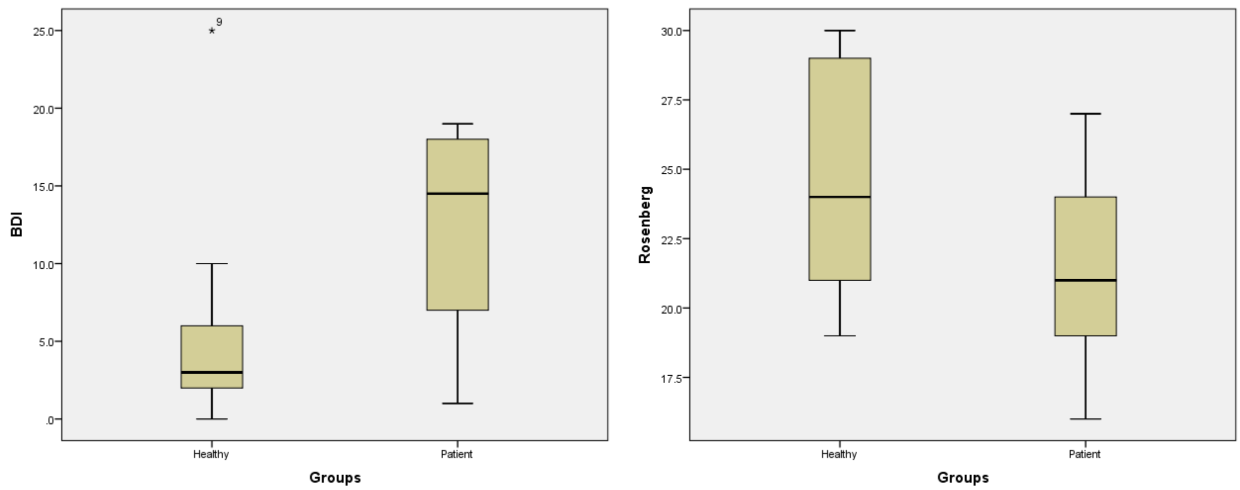

Figure 12: Scores of both groups at Beck Depression Inventory (on left hand) and Rosenberg Self-Esteem Scale.

BCI and Training Performance

Planned between-group comparisons of BCI performance in left hand, right hand and in both hands revealed a statistically significant difference only in the control of right robotic arm (BCI-R: t=2.592, df=18, p=0.018) (Figure 13-Left). Although BCI scores were generally lower than those of healthy (BCI (/160) (mean (SD)) – Healthy: 79.50(18.51); Patients: 66.70(17.49), BCI (%) – Healthy: 49.65%(11.47%); Patients: 41.69%(10.93%), BCI-L – Healthy: 33.70(21.32); Patients: 39.60(19.64), BCI-R – Healthy: 45.80(14.05); Patients: 27.10(17.97)), group difference did not reach statistical significance (BCI (/160): t=1.589, df=18, p=0.129; BCI (%): t=1.590; df=18; p=0.129) (Figure 13-Right). BCI performance on the left hand did not result in any considerable group difference (BCI-L: t=-0.644, df=18, p=0.528). Planned comparisons in BCI scores and outcome based on ASIA classification did not reveal any statistical significant difference in patients' performance depending on their recovery (positive, negative) (BCI(/160): t=-0.598, df=8, p=0.567; BCI (%): t=-0.597, df=8, p=0.567; BCI-L: t=-0.168, df=8, p=0.871; BCI-R: t=-0.390, df=8, p=0.707). However, patients with positive outcome seem to score higher in the BCI control (Figure 14) (BCI (/160) (mean(SD)) – Positive outcome: 69.50(15.00); Negative outcome: 62.50(22.43).

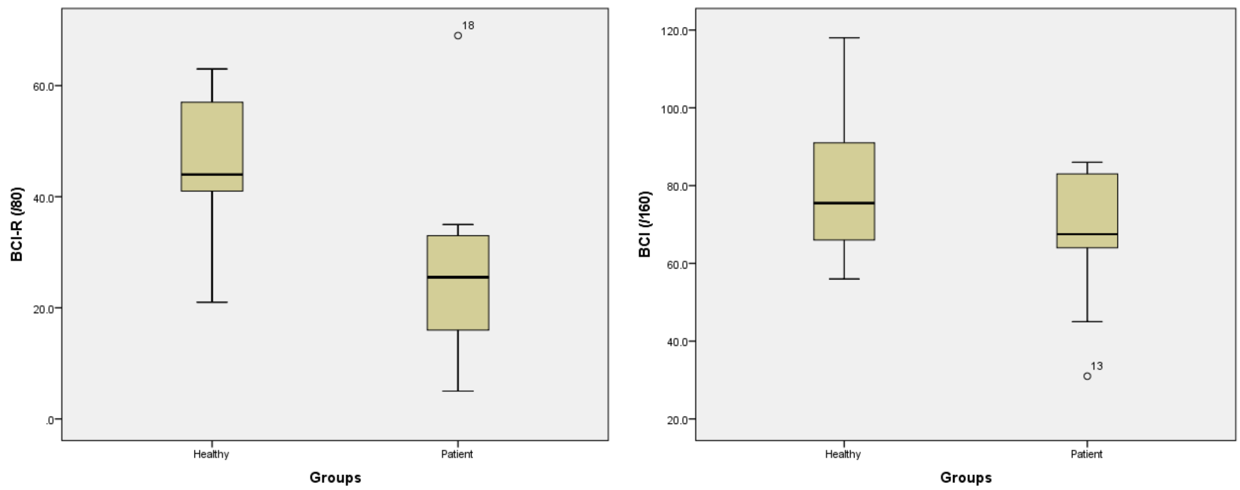

Figure 13: BCI performance of both groups in the control of right hand (on the left) and both hands (on the right).

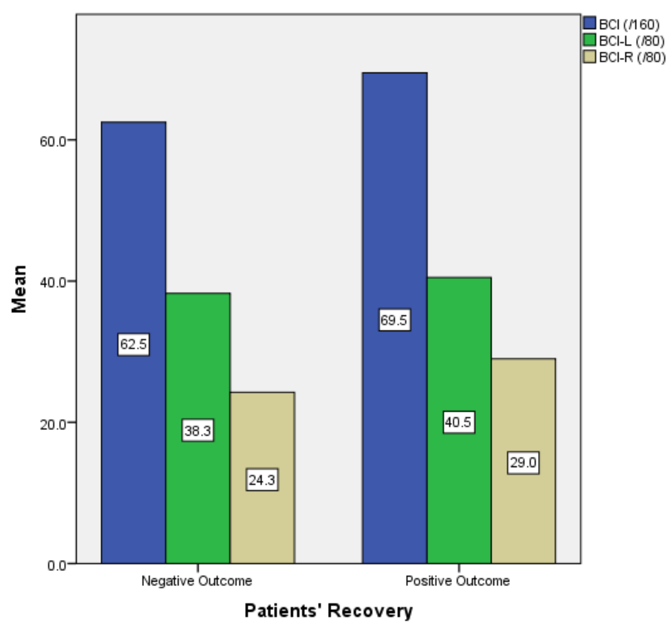

Figure 14: BCI scores in patient group depending on their ASIA classification.

The ability of patients to control robotic arms seem not to be differentiated depending on the injury location (cervical, thoracic) (BCI (/160): t=1.420, df=8, p=0.194; BCI-R: t=0.721, df=8, p=0.491; BCI-L: t=0.498, df=8, p=0.632). However, patients with cervical injuries scored higher than those with thoracic injuries in BCI control (BCI (/160) (mean(SD)) – Cervical: 71.57(14.75); Thoracic: 55.33(21.13), BCI-R – Cervical: 29.86(20.07); Thoracic: 20.67(12.50), BCI-L – Cervical: 41.71(19.20); Thoracic: 34.67(24.03)) (Figure 15).

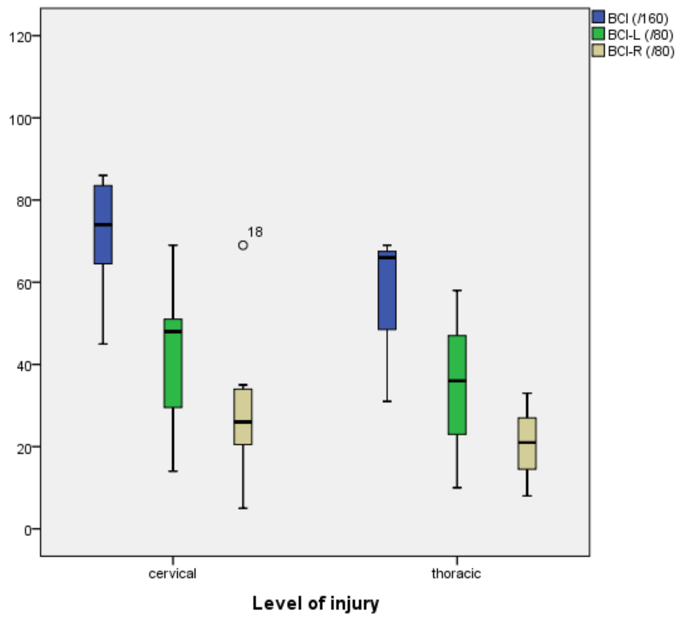

Figure 15: BCI performance of patient group depending on the level of injury.

The BCI performance of both hands was marginally negatively correlated to NLI in patient group (β=-2.656, CI [-5.512, 0.2], p=0.064, adjusted R square=0.286) (Figure 16).

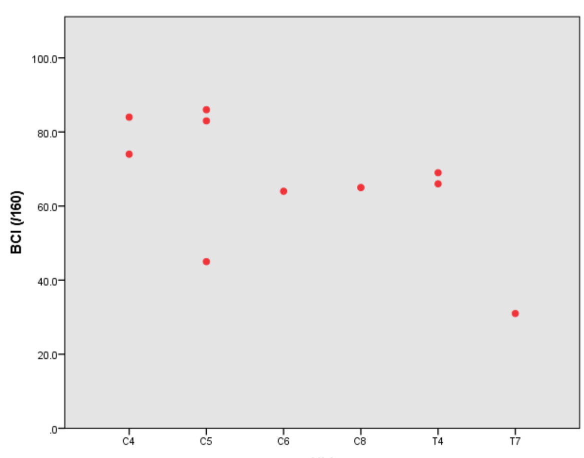

Figure 16: Marginally negative correlation between total BCI scores and NLI.

Negative correlations, but not statistically significant, were found between the BCI performance and the age (BCI (/160) – Healthy (r=-0.361, p=0.305); Patients (r=-0.507, p=0.135), BCI-R – Healthy (r=-0.294, p=0.410); Patients (r=-0.239, p=0.506), BCI-L – Healthy (r=-0.120, p=0.741); Patients (r=-0.233, p=0.517). Total BCI scores were significantly negatively associated with VVIQ total scores (r=-0.727, p=0.017) and VVIQ3 (r_s= -0.948, p<0.001) as well as the BCI-L scores and VVIQ3 (r_s=-0.665, p=0.036). However, other subcategories of VVIQ such as VVIQ1,VVIQ2 and VVIQ4 were not correlated to all BCI scores (BCI (/160)-VVIQ1: r_s =-0.489, p=0.151; BCI-L-VVIQ1: r_s=-0.509, p=0.133; BCI-R-VVIQ1: r_s=-0.194, p=0.590; BCI (/160)-VVIQ2: r=-0.077, p=0.832; BCI-L-VVIQ2: r=-0.073, p=0.840; BCI-R-VVIQ2: r=0.005. p=0.989; BCI (/160)-VVIQ4: r=-0.312, p=0.380; BCI-L-VVIQ4: r=0.026, p=0.943; BCI-R-VVIQ4: r=-0.332, p=0.348).

With regards to BCI performance depending on the depressive symptomatology as assessed by BDI, significant negative correlation was found only between total BCI scores and BDI scores in healthy participants (r_s=-0.719, p=0.019). Correlations explored between all BCI scores and scores at Rosenberg Self-Esteem scale did not reach statistical significance for both groups (Healthy- BCI (/160)-Rosenberg: r=0.150, p=0.679; BCI-L- Rosenberg: r=0.054. p=0.882; BCI-R- Rosenberg: r=0.115, p=0.751; Patients: BCI (/160)-Rosenberg: r=-0.067, p=0.854; BCI-L-Rosenberg: r=-0.397, p=0.255; BCI-R- Rosenberg: r=0.369, p=0.294).

Furthermore, training capacity was investigated between groups using independent samples t-tests since training scores were approximately normally distributed between groups. The training capacity of the two groups seems not to be statistically different neither for the right hand (Train-R: t=0.015, df=18, p=0.988) nor for the left hand (Train-L: t=-0.295, df=18, p=0.771), even if patients showed slightly lower training scores in the right hand and higher in the left hand than healthy participants (Train-R (mean(SD)) – Healthy: 46.40%(10.32%); Patients: 46.30%(18.00%), Train – L – Healthy: 53.80%(16.67%); Patients: 56.20%(19.61%) (Figure 17). Comparing training scores between patients depending on their injury outcome marginally considerable difference was found only in training scores of left hand (Train-L %: (U=3.5, p=0.068), Train-R %: (U=11.50, p=0.915)). Interestingly, patients with negative outcomes trained more efficiently in left hand compared to the patients with positive outcome whereas the opposite was found in the right-hand training (Train-L%: - Positive outcome (median=51.00%, IQR=19.00%); Negative outcome (median=68.00%, IQR=40.00%), Train-R% - Positive outcome (median=48.00%, IQR=40.25%); Negative outcome (median=50.50, IQR=26.50%)) (Figure 18).

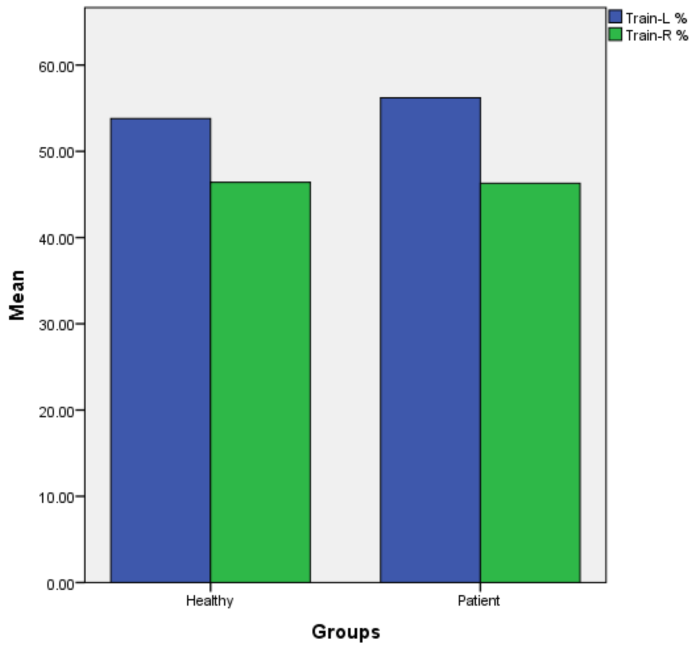

Figure 17: Mean training scores of both groups at left and right hand.

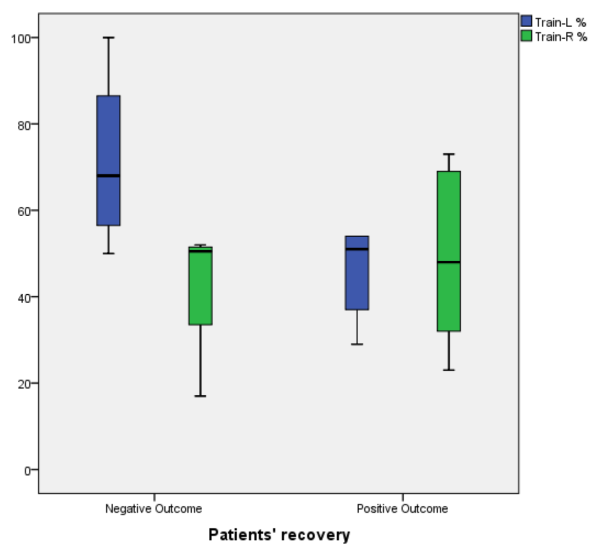

Figure 18: Training scores of patient groups depending on their ASIA classification.

Patients seem not to considerably differentiate their training scores depending on the level of injury (Train-L %: t=-0.590, df=8, p=0.572; Train-R %: t=0.744, df=8, p=0.478). However, it is of high interest to note that training scores in left-hand control were greater in thoracic patients than those with cervical injuries (Train-L % (mean(SD)) – Cervical: 53.71%(22.54%); Thoracic (62.00%(11.53%)) whereas the opposite was the case for the right-hand control (Train-R % (mean(SD)) – Cervical: 49.14%(18.05%); Thoracic: 39.67%(19.66%). The mean BCI and training performance are shown below (Figure 19).

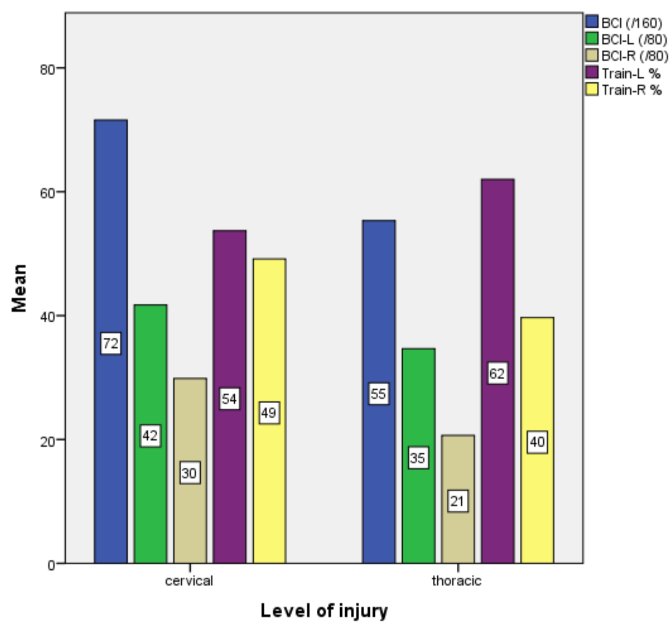

Figure 19: Mean BCI and training performance depending on the level of injury.

Godspeed Questionnaire

Based on planned analysis, healthy and patient participants did not present significant differences in their answers regarding the anthropomorphism (GDSPD-Anthr: t=1.504, df=18, p=0.150), the animacy (GDSPD-Anim: t=0.611, df=18, p=0.549), the likeability (GDSPD-Like: t=-0.217, df=18, p=0.831), the perceived intelligence (GDSPD-Int: t=-0.047, df=18, p=0.963) and the perceived safety (GDSPD-Safe: U=42.0, p=0.536) of robotic arms. Additionally, there was no difference between groups regarding the answers provided to the Godspeed questionnaire (GDSPD (/120): t=0.427, df=18, p=0.675). The scores in Godspeed questionnaire and its subcategories are illustrated below in Figure 20 (GDSPD (/120) (mean(SD)) – Healthy: 80.80(14.78); Patients: 78.00(14.57), GDSPD-Anthr – Healthy: 13.60(4.25); Patients: 10.80(4.08), GDSPD-Anim – Healthy: 18.90(5.11); Patients: 17.70(3.53), GDSPD-Like – Healthy: 18.50(3.87); Patients: 18.90(4.36), GDSPD-Int – Healthy: 17.70(4.60); Patients: 17.80(4.92), GDSPD-Safe – Healthy (median=12.0, IQR=5.3); Patients (median=13.50, IQR=4.5)).

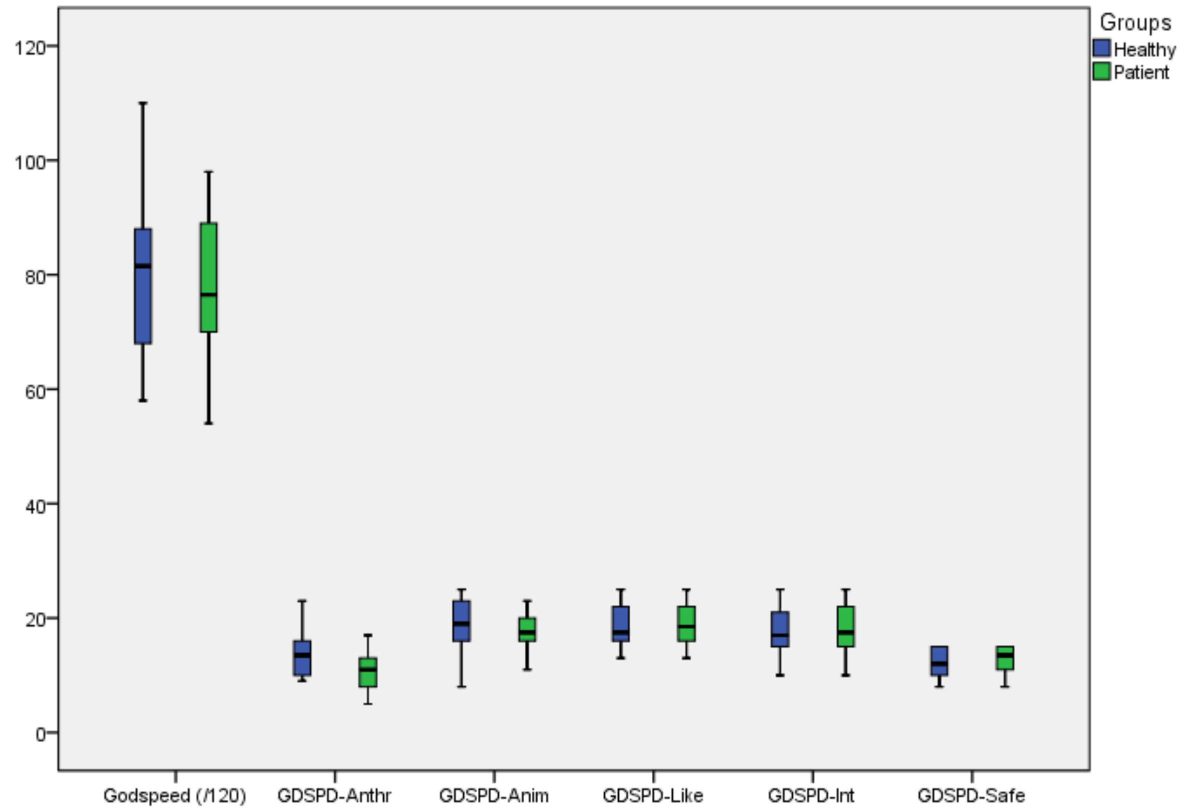

Figure 20: Answers provided to Godspeed questionnaire from both groups.

Godspeed's scores were further explored after grouping by outcome (positive, negative). Marginally significant difference was found only in Goodspeed- Anthropomorphism (t=2.251, df=8, p=0.054) (GDSPD (/120): t=1.918, df=8, 0.091; GDSPS-Anim: t=1.382, df=8, p=0.204; GDSPD-Like: t=1.289, df=8, p=0.233; GDSPD-Int: t=1.343, df=8, p=0.216; GDSPD-Safe: U=10.50, p=0.741). More precisely, patient with negative outcome scored higher than patients with positive outcome in this Godspeed's subcategory (Negative outcome patients: 13.75(3.30); Positive outcome patients: 8.83(3.43)) (Figure 21).

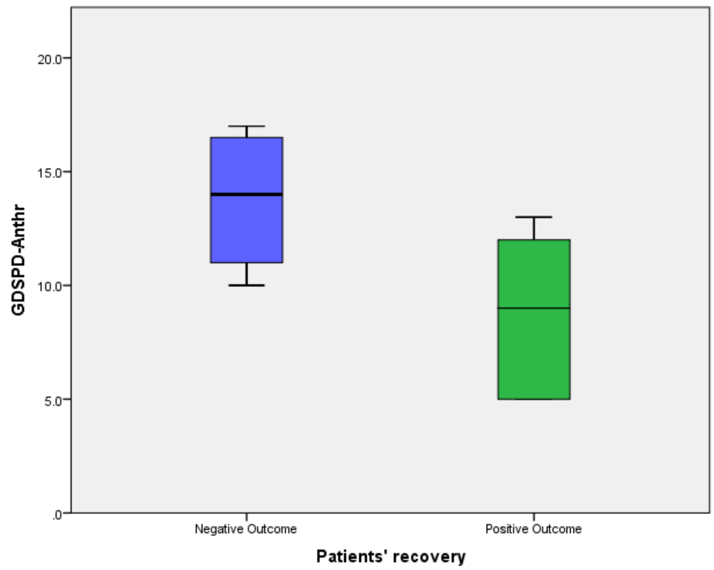

Figure 21: Scores of patients at GDSPD-Anthr depending on outcome

Moreover, significant correlation between Godspeed's and BCI scores was not revealed for both groups (Healthy: GDSPD (/120) – BCI(/160): r=-0.045, p=0.902; GDSPD (/120) – BCI-L: r=-0.236, p=0.512, GDSPD (/120) – BCI-R: r=0.299, p=0.402, GDSPD-Anthr– BCI(/160): r=-0.312, p=0.380, GDSPD-Anthr– BCI-L: r=-0.448, p=0.194, GDSPD-Anthr– BCI-R: r=0.268, p=0.453), GDSPD-Anim– BCI(/160):r=0.340, p=3.336, GDSPD-Anim– BCI-L: r=0.191, p=0.596, GDSPD-Anim– BCI-R: r=0.158, p=0.664, GDSPDS-Like- BCI(/160): r=-0.114, p=0.754, GDSPD-Like- BCI-L: r=-0.437, p=0.206; GDSPD-Like- BCI-R: r=0.513, p=0.129), GDSPD-Int- BCI(/160):r=-0.095, p=0.795, GDSPD-Int- BCI-L: r=-0.173, p=0.632; GDSPD-Int- BCI-R: r=-0.138, p=0.703; GDSPD-Safe- BCI(/160):r=-0.243, p=0.499; GDSPD-Safe- BCI-L: r=-0.006, p=0.986; GDSPD-Safe- BCI-R: r=0.065, p=0.858); Patients - GDSPD (/120) – BCI(/160): r=-0.304, p=0.393; GDSPD (/120) – BCI-L: r=0.170, p=0.638; GDSPD (/120) – BCI-R: r=-0.482, p=0.159 GDSPD-Anthr– BCI(/160): r=-0.160, p=0.659, GDSPD-Anthr– BCI-L: r=0.138, p=0.716, GDSPD-Anthr– BCI-R: r=-0.300, p=0.400, GDSPD-Anim– BCI(/160):r=-0.268, p=0.454, GDSPD-Anim– BCI-L: r=0.059, p=0.871, GDSPD-Anim– BCI-R: r=0.325, p=0.359, GDSPDS-Like- BCI(/160): r=-0.117, p=0.747, GDSPD-Like- BCI-L: r=0.409, p=0.241; GDSPD-Like- BCI-R: r=-0.560, p=0.072), GDSPD-Int- BCI(/160):r=-0.246, p=0.493, GDSPD-Int- BCI-L: r=0.175, p=0.628; GDSPD-Int- BCI-R: r=-0.431, p=0.214; GDSPD-Safe- BCI(/160): r=-0.533, p=0.112; GDSPD-Safe- BCI-L: r=-0.483, p=0.157; GDSPD-Safe- BCI-R: r=-0.227, p=0.529).

The Godspeed's subcategory Intelligence and Anthropomorphism seem to positively correlated to VVIQ4 and VVIQ1 scenario's scores respectively only in healthy (GDSPD-Int – VVIQ4: r=0.654, p=0.040; GDSPD-Anthr – VVIQ1:r=0.629, p=0.052). In patient group, Godspeed's scores in subcategory Perceived safety were positively associated with scores in VVIQ total (r=0.696, p=0.025) and VVIQ1(r=0.780, p=0.008).

Descriptive statistics of Movements:

Movement	Measures of centrality and variation	
	Healthy	Patients
BCI-Far	40.50(8.45)	33.40(9.98)
BCI-Near	39.00(11.95)	33.30(8.82)
BCI-Linear	2.48(0.60)	2.11(0.52)
BCI-Rotational	2.44, 0.72	2.25, 1.06

Between groups differences were explored via independent samples t-tests for variables BCI-Far, BCI-Near and BCI-Linear as they were approximately normally distributed while Mann Whitney U test was used for BCI-Rotational. Based on the planned analysis, no significant outcomes were shown (BCI-Far: t=1.717, df=18, p=0.103; BCI-Near: t=1.213, df=18, p=0.241; BCI-Linear: t=1.286, df=18, p=0.215, BCI-Rotational: U=33.00, p=0.196) (Figure 22).

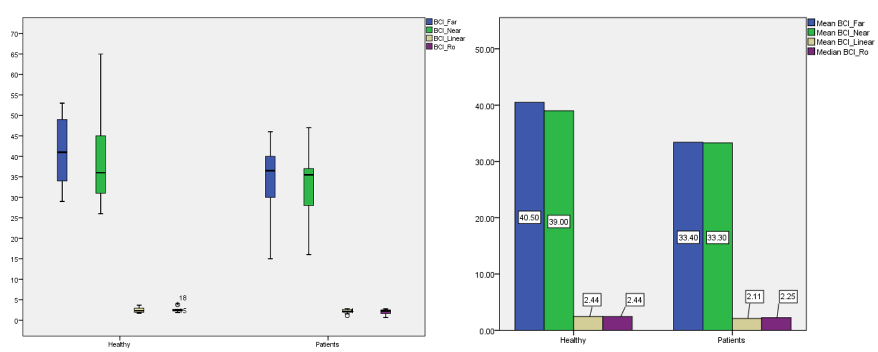

Figure 22: BCI performance of both groups in different categories of movements.

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