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TECHNICAL REPORT

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ANALYSIS OF THE USABILITY OF THE PHYSIOLOGICAL DATA AND DETECTION OF STRESS

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ABSTRACT

This report presented the analyses of the physiological data recorded using E4 wristband for the EMBOA project. The feature extraction process was explained, and the extracted features from the raw physiological signal were provided. The evaluation method for usability of the physiological data for only on the blood volume pulse (BVP) data was explained. Extracted features and reference ranges were utilized to conduct usability analysis. The stress of children was determined using the usable data. Stress were decided using the high frequency (HF) and low frequency (LF) features of BVP data.

Scope of the report:

- data summary;
- usability analysis;
- stress detection.

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1. Data Summary

The number of observations is indicated in Table 1. The data are acquired from Istanbul Technical University (ITU) – Yeditepe University (YU), Macedonian Association for Applied Psychology (MAAP), University of Hertfordshire (UH), and Gdańsk University of Technology (GUT). The data with "bad signal warning" is not included. This data is taken using E4 wristband.

Table 1. Data summary.

Session	Number of Observations	ITU - YU	MAAP	UH	GUT
1	32	12	11	6	3
2	19	2	10	4	3
3	15	-	10	3	2
4	11	-	9	2	-
5	7	-	7	-	-
6	6	-	6	-	-
7	6	-	6	-	-
8	5	-	5	-	-
9	5	-	5	-	-
10	4	-	4	-	-
11	1	-	1	-	-

2. Usability Analysis of ITU-YU, MAAP UH, and GUT Data

The HRV (Heart Rate Variability) features from the Blood Volume Pulse (BVP) signal are used to mark if the signal can be used or not. SDNN (standard deviation of NN intervals where NN or R-R intervals are described as the period between two consecutive heartbeats.), pNN50 (The total number of NN (R-R) intervals divided by the fraction of NN50 intervals where NN50 is described as the number of times two consecutive NN or R-R intervals diverge by more than 50 milliseconds.), RMSSD (Root mean square of the successive differences), and HR (Heart Rate) Mean time-domain features; LF (Low-Frequency Power), and HF (High-Frequency Power) frequency domain features are calculated. Features from the BVP signal are calculated using HeartPy Python [1]. While evaluating ITU-YU data, some segments of these signals are used. The minimum and maximum values were determined for each feature concerning reference [2], [3], [4], [5], [6], [7] values that were presented in Table 3. If the feature value is between the values given in a predetermined range, the signal is labeled as "U" (usable). If the signal from the child is out of range, the signal is labeled as "NU" (non-usable). 2 signal is usable, and 12 signal is non-usable for ITU-YU data. The reference values used to detect the usable and non-usable signals are presented in Table 2.

Table 2. Overall data usability analysis of ITU-YU data.

Name	SDNN	pNN50	RMSSD	HR mean	LF	HF	U/NU
ITU-YU-C01-S01-20210605	no data	no data	no data	no data	no data	no data	NU
ITU-YU-C01-S02-20210702	182.17	0.00	39.84	61.67	7217.99	6852.21	NU
ITU-YU-C02-S01-20210619	150.59	0.19	41.29	200.57	2364.93	5559.90	NU
ITU-YU-C03-S01-20210619	162.04	0.39	67.00	103.28	5300.51	7507.62	NU
ITU-YU-C03-S02-20210702	159.44	0.33	58.88	102.22	2367.96	14824.34	NU
ITU-YU-C04-S01-20210619	151.19	0.20	38.78	196.85	1517.18	4944.00	U
ITU-YU-C05-S01-20210702	artifact	artifact	artifact	artifact	artifact	artifact	NU
ITU-YU-C06-S01-20210810	173.80	0.33	55.24	152.08	747.99	2600.66	NU
ITU-YU-C07-S01-20210810	150.16	0.33	51.98	160.21	1914.06	6154.21	NU
ITU-YU-C08-S01-20210810	224.74	none	none	52.36	none	none	NU
ITU-YU-C09-S01-20210810	artifact	artifact	artifact	artifact	artifact	artifact	NU
ITU-YU-C10-S01-20210810	175.64	0.44	60.52	135.83	1413.27	7056.58	U
ITU-YU-C11-S01-20210810	no data	no data	no data	no data	no data	no data	NU
ITU-YU-C12-S01-20210810	201.31	1.00	109.38	42.20	0.00	0.00	NU

Table 3. Reference values.

Ref.	Age	Time-domain			HR Mean (bpm)	Frequency -domain		ASD	M/F
		SDNN (ms)	pNN50 (%)	RMSSD (ms)		HF (ms ²)	LF (ms ²)		
[2]	18-33	70.12 ± 28.03	19.78 ± 9.46	71.44 ± 53.99	none	910.10 ± 915.31	1020.00 ± 1016.20	no	M
[2]	18-33	70.90 ± 29.13	23.17 ± 10.27	77.431 ± 35.82	none	731.79 ± 901.30	1261.69 ± 1237.95	no	F
[3]	6-8	25.00-116.00	2.20-71.90	22.00-149.00	69.20-101.80	221.00-3124.00	188.00-7690.00	no	M & F
[4]	7.40 ± 1.10	133.00 ± 32.00	24.00 ± 11.00	75.00 ± 50.00	none	none	none	no	F
[4]	7.00 ± 1.40	154.00 ± 33.00	31.00 ± 17.00	97.00 ± 65.00	none	none	none	no	M
[5]	4-17	51.00-236.00	6.00-48.00	25.00-92.00	99.62	406.30-2200.60	173.30-1612.10	no	M & F
[6]	7-12	154.10 ± 40.20	None	44.00 ± 35.40	none	1889.50 ± 1116.00	2308.40 ± 1958.40	no	M & F
[7]	10.70 ± 0.90	none	none	none	72.00 ± 9.00	2243.00 ± 3230.00	3127.00 ± 3911.00	yes	M & F

To assess the usability of MAAP, UH, and GUT data same reference range in Table 3 is used. The six features were presented in Table 3 were evaluated for usability analysis. From Table 3, for each feature, minimum and maximum values are taken to be the broadest range considering every row. For instance, for SDNN maximum value is taken as 154.10 ms, and the minimum value is taken as 25 ms. If the feature is in the predetermined range, then the feature is scored as 1. For each signal, the total score is calculated. If the score is higher than 3, it is labeled as "U" (usable). If the score is 3 or less than 3, then it is labeled as "NU" (non-usable) (Table 4). For MAAP data, 53 signals are determined as usable, 21 signals are determined as non-usable. For UH data, 8 signals are determined as usable, 7 signals are determined as non-usable. For GUT data, 6 signals are determined as usable, 2 signals are determined as non-usable. The details of how the score has been calculated are presented in Table 5.

Table 4. Overall Usability Analysis of MAAP and UH Data

	SDNN	pNN50	RMSSD	HR mean	LF	HF	Score	U/NU
MAAP								
MAAP-C02-S02-20200915-Wristband 37'	155.22	0.66	210.57	98.36	4716.10	8258.59	4	U
MAAP-C02-S03-20200917-Wristband 32'	162.42	0.64	219.00	102.30	8400.63	11154.66	3	NU
MAAP-C03-S01-20200907-Wristband 54'	158.38	0.78	205.19	83.97	2111.73	8947.99	3	NU

MAAP- C02-S01- 20200908- Wristband 48'	112.54	0.49	147.09	124.50	635.16	2329.35	6	U
MAAP- C01-S01- 20200907- Wristband 52'	170.48	0.77	231.28	82.01	6305.05	9621.83	2	NU
MAAP- C01-S02- 20200914- Wristband 42'	162.60	0.77	246.86	87.58	1687.34	16725.43	3	NU
MAAP- C03-S02- 20200914- Wristband 44'	129.05	0.60	154.88	99.66	2481.76	3992.80	6	U
MAAP- C03-S03- 20200915- Wristband 39'	132.18	0.67	185.60	104.26	1724.20	3648.45	5	U
MAAP- C01-S04- 20201005- Wristband 55'	151.71	0.78	211.55	86.62	1730.77	7442.45	4	U
MAAP- C01-S03- 20200921- Wristband 28'	172.05	0.68	205.82	75.65	3545.64	19076.84	4	U
MAAP- C04-S01- 20200908- Wristband 49'	127.36	0.22	136.39	193.85	4819.04	5662.50	6	U
MAAP- C03-S10- 20201007- Wristband'	142.86	0.88	264.58	82.47	2485.80	6131.24	4	U
MAAP- C03-S04- 20200921- Wristband 30'	134.22	0.83	129.48	65.94	1634.41	9635.36	4	U
MAAP- C03-S05- 20200922- Wristband 23'	154.89	0.74	212.86	98.98	1502.97	5819.07	4	U

MAAP- C03-S08- 20201005- Wristband 61'	157.84	0.80	219.86	95.38	5033.88	13002.71	3	NU
MAAP- C04-S03- 20200915- Wristband 38'	124.08	0.55	156.23	110.25	3715.36	4228.69	6	U
MAAP- C03-S07- 20200929- Wristband 8'	155.93	0.81	217.88	82.56	4603.90	8235.80	3	NU
MAAP- C04-S04- 20200917- Wristband 34'	154.81	0.74	205.13	97.69	2426.87	8502.25	3	NU
MAAP- C03-S06- 20200928- Wristband 13'	151.59	0.71	204.93	104.90	2359.77	7147.95	5	U
MAAP- C03-S09- 20201006- Wristband'	168.98	0.80	224.32	95.94	6950.90	9623.20	2	NU
MAAP- C04-S08- 20201001- Wristband 1'	91.53	0.39	114.45	117.52	2213.77	2751.92	6	U
MAAP- C04-S09- 20201006- Wristband'	133.17	0.65	189.92	113.23	1924.66	3641.03	5	U
MAAP- C04-S10- 20201013- Wristband'	169.46	0.77	252.56	86.48	3497.97	12006.82	3	NU
MAAP- C05-S03- 20200928- Wristband 9'	165.38	0.78	229.20	72.36	6124.49	10852.54	2	NU
MAAP- C05-S01- 20200921- Wristband 24'	207.67	1.00	375.00	42.48	0.00	10277.31	2	NU
MAAP- C05-S04- 20201001-	118.16	0.62	157.42	108.88	3540.54	5957.28	6	U

Wristband 2'									
MAAP- C05-S02- 20200924- Wristband 14'	113.94	0.68	150.34	105.21	2224.73	4736.56	6	U	
MAAP- C04-S06- 20200924- Wristband 18'	109.54	0.52	161.50	120.10	1023.62	2226.31	6	U	
MAAP- C04-S05- 20200922- Wristband 22'	141.58	0.69	200.43	99.46	3365.14	7014.45	5	U	
MAAP- C04-S07- 20200929- Wristband 7'	159.61	0.84	199.03	102.03	1703.84	9722.56	3	NU	
MAAP- C06-S04- 20201005- Wristband 59'	107.75	0.65	156.02	112.63	694.32	3109.05	6	U	
MAAP- C06-S01- 20200921- Wristband 25'	127.83	0.60	158.23	94.81	4544.25	7612.23	6	U	
MAAP- C07-S03- 20200928- Wristband 11'	112.64	0.66	159.65	116.45	1142.75	2709.47	6	U	
MAAP- C05-S05- 20201005- Wristband 60'	170.69	0.78	258.26	84.97	1278.64	4411.74	4	U	
MAAP- C06-S03- 20200928- Wristband 10'	161.19	1.00	297.70	63.73	2549.35	13072.25	3	NU	
MAAP- C07-S05- 20201005- Wristband 58'	100.39	0.58	135.95	108.25	1649.57	2818.02	6	U	
MAAP- C07-S02- 20200922-	130.36	0.56	143.66	133.41	1764.57	1971.87	6	U	

Wristband 21'								
MAAP- C07-S04- 20200929- Wristband 6'	121.60	0.65	162.91	109.32	2070.18	4377.26	5	U
MAAP- C07-S01- 20200921- Wristband 26'	143.82	0.92	183.40	84.73	418.19	2685.96	4	U
MAAP- C06-S02- 20200924- Wristband 15'	121.08	0.71	166.56	96.93	2555.04	4156.18	5	U
MAAP- C08-S07- 20200924- Wristband 19'	115.76	0.55	158.89	110.25	1898.14	6030.56	6	U
MAAP- C08-S08- 20200928- Wristband 12'	111.49	0.58	153.99	111.82	694.65	2767.90	6	U
MAAP- C08-S03- 20200910- Wristband 46'	124.30	0.75	184.99	113.57	1532.11	5119.91	4	U
MAAP- C08-S02- 20200908- Wristband 50'	134.12	0.77	189.68	113.52	1441.51	4753.35	4	U
MAAP- C07-S06- 20201006- Wristband'	143.18	0.79	177.10	94.25	4891.81	6332.65	4	U
MAAP- C07-S07- 20201007- Wristband'	118.97	0.78	171.11	106.72	1928.08	5872.63	4	U
MAAP- C08-S04- 20200914- Wristband 43'	153.91	0.72	212.29	107.31	5658.01	5636.56	4	U
MAAP- C08-S01- 20200907- Wristband 53'	125.93	0.83	203.53	63.55	0.00	4648.08	4	U

MAAP- C08-S05- 20200917- Wristband 35'	162.35	0.88	254.65	84.73	3003.46	7526.41	4	U
MAAP- C08-S06- 20200921- Wristband 29'	109.98	0.49	139.27	109.56	1149.85	2400.00	6	U
MAAP- C09-S01- 20200907- Wristband 51'	153.74	1.00	242.63	68.98	1939.44	4378.14	4	NU
MAAP- C08-S11- 20201007- Wristband'	112.44	0.43	142.47	119.04	1458.88	4461.10	6	U
MAAP- C09-S03- 20200910- Wristband 45'	127.63	0.67	160.45	126.20	959.99	3613.39	6	U
MAAP- C09-S05- 20200917- Wristband 33'	169.64	0.77	238.07	89.59	1848.26	9183.13	3	NU
MAAP- C09-S02- 20200908- Wristband 47'	113.23	0.60	150.11	119.88	1562.29	2986.51	6	U
MAAP- C09-S04- 20200914- Wristband 41'	109.73	0.54	144.62	121.09	986.97	1465.20	6	U
MAAP- C08-S09- 20201001- Wristband 4'	150.57	0.88	205.29	88.77	4923.20	8760.25	3	NU
MAAP- C09-S06- 20200921- Wristband 27'	176.18	0.85	268.59	86.88	4973.06	7424.16	4	U
MAAP- C08-S10- 20201005- Wristband 57'	90.85	0.44	117.38	119.38	735.89	4568.50	6	U

MAAP- C09-S07- 20200924- Wristband 17'	96.13	0.33	120.87	121.60	974.56	1198.24	6	U
MAAP- C09-S10- 20201007- Wristband'	124.21	0.68	174.82	114.07	1025.37	5243.14	5	U
MAAP- C10-S04- 20200922- Wristband 20'	154.90	0.81	209.58	103.01	2568.79	9202.41	3	NU
MAAP- C09-S09- 20201006- Wristband'	110.99	0.58	156.41	121.18	1022.19	2918.00	6	U
MAAP- C10-S05- 20200924- Wristband 16'	160.72	0.79	222.75	93.34	5861.14	7369.86	3	NU
MAAP- C10-S02- 20200915- Wristband 36'	163.21	0.79	194.81	94.87	6652.97	6933.54	3	NU
MAAP- C10-S06- 20200929- Wristband 5'	149.48	0.78	193.11	87.38	2689.78	9691.15	3	NU
MAAP- C10-S03- 20200917- Wristband 31'	117.96	0.49	128.44	95.59	2462.05	5286.21	6	U
MAAP- C10-S01- 20200914- Wristband 40'	94.84	0.57	126.25	97.51	1480.45	1133.06	6	U
MAAP- C10-S07- 20201001- Wristband 3'	152.83	0.87	233.95	90.25	1485.12	8494.68	3	NU
MAAP- C09-S08- 20201005- Wristband 56'	168.49	0.62	249.63	81.31	6011.72	8586.90	3	NU
MAAP- C10-S08-	114.63	0.55	167.79	105.94	1059.85	2711.26	5	U

20201006- Wristband'									
MAAP- C11-S02- 20201013- Wristband'	147.80	0.86	224.83	109.53	2955.96	4078.81	4	U	
MAAP- C10-S09- 20201013- Wristband'	144.25	0.77	199.68	100.19	1795.27	5818.76	4	U	
MAAP- C11-S01- 20201007- Wristband'	140.45	0.80	153.25	82.07	0.00	12622.44	4	U	
UH									
UH-C02- S01- 20210624- Wristband'	107.00	0.43	112.18	79.74	1138.00	2516.49	6	U	
UH-C03- S01- 20210624- Wristband'	102.32	0.48	121.90	76.88	2014.08	3540.93	6	U	
UH-C04- S01- 20210624- Wristband- b'	153.19	0.70	201.31	115.14	0.00	6103.18	5	U	
UH-C05- S01- 20210624- Wristband'	195.21	0.67	251.30	44.29	2820.19	17034.23	3	NU	
UH-C06- S01- 20210624- Wristband'	110.83	0.48	160.70	82.38	1676.63	3767.72	6	U	
UH-C04- S02- 20210625- Wristband'	118.32	0.28	141.06	101.91	3238.81	3704.20	6	U	
UH-C01- S02- 20210625- Wristband'	159.25	0.81	241.38	86.48	2408.77	8727.81	3	NU	
UH-C05- S03- 20210629- Wristband'	182.16	0.57	127.49	60.41	5712.19	12273.52	3	NU	
UH-C06- S02- 20210629- Wristband'	175.44	0.53	211.34	82.07	768.03	18250.40	4	U	
UH-C01- S03-	164.29	0.84	249.38	91.94	3516.42	8275.37	3	NU	

20210629- Wristband'									
UH-C03- S02- 20210629- Wristband'	157.72	0.83	230.12	77.07	6989.40	8182.64	2	NU	
UH-C04- S03- 20210629- Wristband'	156.42	0.79	210.94	80.19	2317.41	14444.53	3	NU	
UH-C04- S04- 20210630- Wristband'	147.67	0.80	245.27	69.67	1975.52	8314.38	3	NU	
UH-C05- S04- 20210630- Wristband'	150.12	0.72	187.00	89.56	3436.62	9505.65	4	U	
UH-C07- S01- 20210630- Wristband'	149.45	0.75	113.21	67.29	407.75	7850.58	4	U	
GUT									
GUT-C02- S03- 20210628- Wirstband'	163.27	0.88	238.92	79.86	2473.15	11533.34	3	NU	
'GUT- C02-S01- 20210618- Wirstband'	161.11	1.00	203.13	59.90	0.00	2032.68	3	NU	
'GUT- C03-S02- 20210621- Wirstband'	127.77	0.68	188.09	101.18	1538.34	3874.44	5	U	
'GUT-C01- S03- 20210628- Wirstband'	131.71	0.71	176.31	94.95	3592.10	6421.45	5	U	
'GUT- C03-S01- 20210618- Wirstband'	100.59	0.46	133.27	104.36	911.37	1724.07	6	U	
'GUT-C01- S02- 20210621- Wirstband'	112.27	0.68	162.70	97.69	1119.48	2508.22	5	U	
'GUT- C02-S02- 20210621- Wirstband'	122.38	0.72	180.84	87.62	2545.38	3847.86	5	U	
'GUT-C01- S01- 20210618- Wirstband	92.28	0.61	131.29	97.10	430.46	1709.72	6	U	

Table 5. Score Calculation from the Features for MAAP and UH Data.

	SDNN	pNN50	RMSSD	HR Mean	LF	HF	Total
MAAP							
MAAP-C02-S02-20200915- Wristband 37'	1	1	0	1	1	0	4
MAAP-C02-S03-20200917- Wristband 32'	1	1	0	1	0	0	3
MAAP-C03-S01-20200907- Wristband 54'	1	0	0	1	1	0	3
MAAP-C02-S01-20200908- Wristband 48'	1	1	1	1	1	1	6
MAAP-C01-S01-20200907- Wristband 52'	1	0	0	1	0	0	2
MAAP-C01-S02-20200914- Wristband 42'	1	0	0	1	1	0	3
MAAP-C03-S02-20200914- Wristband 44'	1	1	1	1	1	1	6
MAAP-C03-S03-20200915- Wristband 39'	1	1	0	1	1	1	5
MAAP-C01-S04-20201005- Wristband 55'	1	0	0	1	1	1	4
MAAP-C01-S03-20200921- Wristband 28'	1	1	0	1	1	0	4
MAAP-C04-S01-20200908- Wristband 49'	1	1	1	1	1	1	6
MAAP-C03-S10-20201007- Wristband'	1	0	0	1	1	1	4
MAAP-C03-S04-20200921- Wristband 30'	1	0	1	1	1	0	4
MAAP-C03-S05-20200922- Wristband 23'	1	0	0	1	1	1	4
MAAP-C03-S08-20201005- Wristband 61'	1	0	0	1	1	0	3
MAAP-C04-S03-20200915- Wristband 38'	1	1	1	1	1	1	6
MAAP-C03-S07-20200929- Wristband 8'	1	0	0	1	1	0	3
MAAP-C04-S04-20200917- Wristband 34'	1	0	0	1	1	0	3
MAAP-C03-S06-20200928- Wristband 13'	1	1	0	1	1	1	5
MAAP-C03-S09-20201006- Wristband'	1	0	0	1	0	0	2
MAAP-C04-S08-20201001- Wristband 1'	1	1	1	1	1	1	6
MAAP-C04-S09-20201006- Wristband'	1	1	0	1	1	1	5
MAAP-C04-S10-20201013- Wristband'	1	0	0	1	1	0	3
MAAP-C05-S03-20200928- Wristband 9'	1	0	0	1	0	0	2
MAAP-C05-S01-20200921- Wristband 24'	1	0	0	0	1	0	2

MAAP-C05-S04-20201001- Wristband 2'	1	1	1	1	1	1	6
MAAP-C05-S02-20200924- Wristband 14'	1	1	1	1	1	1	6
MAAP-C04-S06-20200924- Wristband 18'	1	1	1	1	1	1	6
MAAP-C04-S05-20200922- Wristband 22'	1	1	0	1	1	1	5
MAAP-C04-S07-20200929- Wristband 7'	1	0	0	1	1	0	3
MAAP-C06-S04-20201005- Wristband 59'	1	1	1	1	1	1	6
MAAP-C06-S01-20200921- Wristband 25'	1	1	1	1	1	1	6
MAAP-C07-S03-20200928- Wristband 11'	1	1	1	1	1	1	6
MAAP-C05-S05-20201005- Wristband 60'	1	0	0	1	1	1	4
MAAP-C06-S03-20200928- Wristband 10'	1	0	0	1	1	0	3
MAAP-C07-S05-20201005- Wristband 58'	1	1	1	1	1	1	6
MAAP-C07-S02-20200922- Wristband 21'	1	1	1	1	1	1	6
MAAP-C07-S04-20200929- Wristband 6'	1	1	0	1	1	1	5
MAAP-C07-S01-20200921- Wristband 26'	1	0	0	1	1	1	4
MAAP-C06-S02-20200924- Wristband 15'	1	1	0	1	1	1	5
MAAP-C08-S07-20200924- Wristband 19'	1	1	1	1	1	1	6
MAAP-C08-S08-20200928- Wristband 12'	1	1	1	1	1	1	6
MAAP-C08-S03-20200910- Wristband 46'	1	0	0	1	1	1	4
MAAP-C08-S02-20200908- Wristband 50'	1	0	0	1	1	1	4
MAAP-C07-S06-20201006- Wristband'	1	0	0	1	1	1	4
MAAP-C07-S07-20201007- Wristband'	1	0	0	1	1	1	4
MAAP-C08-S04-20200914- Wristband 43'	1	1	0	1	0	1	4
MAAP-C08-S01-20200907- Wristband 53'	1	0	0	1	1	1	4
MAAP-C08-S05-20200917- Wristband 35'	1	0	0	1	1	1	4
MAAP-C08-S06-20200921- Wristband 29'	1	1	1	1	1	1	6
MAAP-C09-S01-20200907- Wristband 51'	1	0	0	1	1	1	4
MAAP-C08-S11-20201007- Wristband'	1	1	1	1	1	1	6

MAAP-C09-S03-20200910- Wristband 45'	1	1	1	1	1	1	6
MAAP-C09-S05-20200917- Wristband 33'	1	0	0	1	1	0	3
MAAP-C09-S02-20200908- Wristband 47'	1	1	1	1	1	1	6
MAAP-C09-S04-20200914- Wristband 41'	1	1	1	1	1	1	6
MAAP-C08-S09-20201001- Wristband 4'	1	0	0	1	1	0	3
MAAP-C09-S06-20200921- Wristband 27'	1	0	0	1	1	1	4
MAAP-C08-S10-20201005- Wristband 57'	1	1	1	1	1	1	6
MAAP-C09-S07-20200924- Wristband 17'	1	1	1	1	1	1	6
MAAP-C09-S10-20201007- Wristband'	1	1	0	1	1	1	5
MAAP-C10-S04-20200922- Wristband 20'	1	0	0	1	1	0	3
MAAP-C09-S09-20201006- Wristband'	1	1	1	1	1	1	6
MAAP-C10-S05-20200924- Wristband 16'	1	0	0	1	0	1	3
MAAP-C10-S02-20200915- Wristband 36'	1	0	0	1	0	1	3
MAAP-C10-S06-20200929- Wristband 5'	1	0	0	1	1	0	3
MAAP-C10-S03-20200917- Wristband 31'	1	1	1	1	1	1	6
MAAP-C10-S01-20200914- Wristband 40'	1	1	1	1	1	1	6
MAAP-C10-S07-20201001- Wristband 3'	1	0	0	1	1	0	3
MAAP-C09-S08-20201005- Wristband 56'	1	1	0	1	0	0	3
MAAP-C10-S08-20201006- Wristband'	1	1	0	1	1	1	5
MAAP-C11-S02-20201013- Wristband'	1	0	0	1	1	1	4
MAAP-C10-S09-20201013- Wristband'	1	0	0	1	1	1	4
MAAP-C11-S01-20201007- Wristband'	1	0	1	1	1	0	4
UH							
UH-C02-S01-20210624- Wristband'	1	1	1	1	1	1	6
UH-C03-S01-20210624- Wristband'	1	1	1	1	1	1	6
UH-C04-S01-20210624- Wristband-b'	1	1	0	1	1	1	5
UH-C05-S01-20210624- Wristband'	1	1	0	0	1	0	3

UH-C06-S01-20210624- Wristband'	1	1	1	1	1	1	6
UH-C04-S02-20210625- Wristband'	1	1	1	1	1	1	6
UH-C01-S02-20210625- Wristband'	1	0	0	1	1	0	3
UH-C05-S03-20210629- Wristband'	1	1	1	0	0	0	3
UH-C06-S02-20210629- Wristband'	1	1	0	1	1	0	4
UH-C01-S03-20210629- Wristband'	1	0	0	1	1	0	3
UH-C03-S02-20210629- Wristband'	1	0	0	1	0	0	2
UH-C04-S03-20210629- Wristband'	1	0	0	1	1	0	3
UH-C04-S04-20210630- Wristband'	1	0	0	1	1	0	3
UH-C01-S04-20210630- Wristband'	1	0	0	1	0	0	2
UH-C05-S04-20210630- Wristband'	1	1	0	1	1	0	4
UH-C07-S01-20210630- Wristband'	1	0	1	1	1	0	4
GUT							
'GUT-C02-S03-20210628- Wristband'	1	0	0	1	1	0	3
'GUT-C02-S01-20210618- Wristband'	1	0	0	0	1	1	3
'GUT-C03-S02-20210621- Wristband'	1	1	0	1	1	1	5
'GUT-C01-S03-20210628- Wristband'	1	1	0	1	1	1	5
'GUT-C03-S01-20210618- Wristband'	1	1	1	1	1	1	6
'GUT-C01-S02-20210621- Wristband'	1	1	0	1	1	1	5
'GUT-C02-S02-20210621- Wristband'	1	1	0	1	1	1	5
'GUT-C01-S01-20210618- Wristband	1	1	1	1	1	1	6

3. Stress Detection

The stress value has also been calculated considering the collected and usable data. LF power has been shown to increase, and HF power has decreased during stress conditions. In their study, Tiiananen et al. calculated HRV stress indices of 20 children (age 10.7 ± 0.9 years, 6 girls, 14 boys) with Asperger Syndrome (AS) and 21 typically developed children (age: 10.9 ± 1 years, 9 girls, 12 boys) for the control group. The reference values in Table 6 are taken from Tiiananen et al. [7]. The reference values and the values obtained from EMBOA data are presented in Table 6. In Table 6 for MAAP, ITU-YU, and UH, LF power increases for GUT LF power decreases, and also, HF power increases with respect to children with AS reference for all countries. It is not possible to detect stress from this data. The reference values and the values obtained from the usable EMBOA

data are presented in Table 7. As shown in Table 7 for MAAP data, LF power decreases and HF power increases concerning children with AS reference. It shows the non-stress condition. For UH, LF power decreases, and HF power increases with respect to children with AS reference. It also shows the non-stress condition. For GUT, LF power decreases, and HF power increases with respect to children with AS reference. It also shows the non-stress condition.

Table 6. Stress table for overall data.

Parameter	Control (Reference)	Children with AS (Reference)	Children with AS overall data (MAAP)	Children with AS (ITU-YU)	Children with AS overall data (UH)	Children with AS overall data (GUT)
LF Power (ms²)	1480.00 ± 1850.00	2243.00 ± 3230.00	2605.24 ± 1859.86	2538.21 ± 2289.51	2561.32 ± 1883.92	1576.29 ± 1210.48
HF Power (ms²)	1693.00 ± 1844.00	3127.00 ± 3911.00	6412.36 ± 3575.70	6166.61 ± 4816.31	8832.78 ± 4847.85	4206.47 ± 3355.88
HR (bpm)	75.00 ± 11.00	72.00 ± 9.00	99.98 ± 20.26	116.51 ± 57.65	80.33 ±16.79	90.33 ± 14.54
LF/HF Ratio		1.09 ± 0.79	0.45 ± 0.26	0.43 ± 0.30	0.36 ± 0.27	0.38 ± 0.22

Table 7. Stress table for usable data.

Parameter	Control (Reference)	Children with AS (Reference)	Children with AS usable data (MAAP)	Children with AS usable data (UH)	Children with AS usable data (GUT)
LF Power (ms²)	1480.00 ± 1850.00	2243.00 ± 3230.00	2063.22 ± 1338.69	1584.99 ± 1260.47	1689.52 ± 1173.96
HF Power (ms²)	1693.00 ± 1844.00	3127.00 ± 3911.00	4991.46 ±2961.59	6904.89 ± 5178.00	3347.63 ± 1788.83
HR (bpm)	75.00 ± 11.00	72.00 ± 9.00	105.20 ±20.06	86.87 ± 15.17	97.17 ± 5.73
LF/HF Ratio		1.09±0.79	0.46 ± 0.26	0.35 ± 0.30	0.47 ± 0.14

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