"Music Intervention for Stress Reduction (MISTRESS)"

Phase 1 Results

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Summary of Findings

- For each of the three independent stress indicators it was found that:
  - The mean stress reduction in the music intervention group (INMU) was greater than the control group when destressing. The reduction was found to be significant for the Sumondo Stress Score.
  - The percentage of patients which were able to destress was greater in the INMU group than in the control group.
  - For the subjects who were able to destress in the control group, the destressing magnitude was lower than those subjects that destressed in the INMU group.
- From questionnaires aimed at quantifying the emotional state of the subjects
  - The subjects using INMU device for the destressing exhibited a more positive emotion, one which was akin to their pre-stressed state. This was not achieved by the control group.

1. AIM

The project investigates the effects of music intervention for stress reduction in relation to Adaptimus' INMU adaptive music system and Sumondo's stress evaluation app. Through lab experiments involving physiological measurements and psychometric testing, the hypothesis that adaptive music stimulus (using INMU) has a better stress reducing effect than a control group with no music was tested. The methodology involves a stressor that invokes physiological and psychological stress, after which the reduction in stress level as described by the different stress indicators is measured and analyzed for both groups.

2. EXPERIMENT SUMMARY

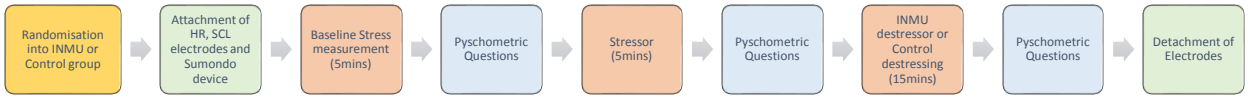


Figure 1: Summary of MISTRESS Phase 1 Experiment

The experiment has three distinct phases. 5 minutes of baseline readings in order to account for baseline changes across patients, 5 minutes of a game-like task designed to invoke a stressful state in the subject, and 15 minutes of a destressor period. A total of 17 subjects enrolled for the

experiments. 9 and 8 subjects were randomly assigned to one of the 2 condition groups respectively:

i) INMU Touch device
ii) No device (Control)

These were the two different destressors tested with hypothesis being that the condition i) is a better destressor than the control ii). Stress reduction was assessed via four main stress indicators:

a) Subject's increase in Sumondo stress score.
b) Subject's reduction in heart rate.
c) Subject's increase in skin resistance levels.
d) Subject's answers to psychometric testing questions (Affect Grid).

For the stressor, a set of cognitive time limited tasks designed to generate a physiological stress response in the test subjects was performed. This involves a number of tasks that the subject is asked to perform within a time-limit, during which, the subject is shown a negative score compared to other participants' scores. The value of the negative score is shown independently of the actual score the current subject is having. This method has been shown to invoke a physiological stress response in [2] and confirmed in a previous study that assessed the effects of music familiarity in stress reduction [1].

3. METHOD OF DATA EXTRACTION AND ANALYSIS

Stress monitoring was performed by three methods. The first and second being through physiological measurements, namely the skin resistance level (SRL) – extracted from the galvanic skin response (GSR) signal and heart rate (HR) extracted from the photoplethysmogram (PPG) signal. Both of which have been shown to be directly related to stress levels [3-5]. The third means will be through the Sumondo device which assigns an average stress score from its PPG recordings of its wrist device. A Shimmer3 device [6] streaming data via BlueTooth was used for the PPG and GSR signal extraction. The PPG signal was extracted from the left ear lobe of the subject at 256Hz and the GSR was recorded on the left index finger using two dry electrodes at also at 256Hz. 30 second windows with 50% overlap were used to extract the heart rate from the distance between peaks of the PPG signal using Matlab scripts devised in [1]. Stress scores generated from the Sumondo watch were extracted from the Sumondo mobile application. Physiological data was extracted for all subjects, except for 3 in which the Shimmer devices failed to stream data mid-experiment, resulting in unusable PPG and GSR data. For these subjects the Sumondo recording was unaffected. P-values for assessing changes in distributions between the INMU and control groups were performed using the Student's T-Test assuming equal variance. Even though the normality assumption does not hold for all distributions compared, even for highly skewed data, having this assumption is one which does not cause significant Type-I errors [7]. The T-Test was

paired when comparing changes between the same subjects across different states and unpaired when comparing different subjects from the two groups.

Psychometric testing of the subjects included the following:

- Before the stressor
  - Fill in 'affect grid' devised in [8] shown in figure 1.
- After the stressor:
  - Answering whether they were ashamed about their performance in the task
  - Fill in 'affect grid' devised in [8] shown in figure 1.
- After INMU Destressor condition
  - Answering whether they were ashamed about their performance in the task
  - Answering whether they thought about their performance in the task while listening to the music
  - Fill in 'affect grid' devised in [8] shown in figure 1.
  - Fill out the AIMS (Absorption into music score) [9].

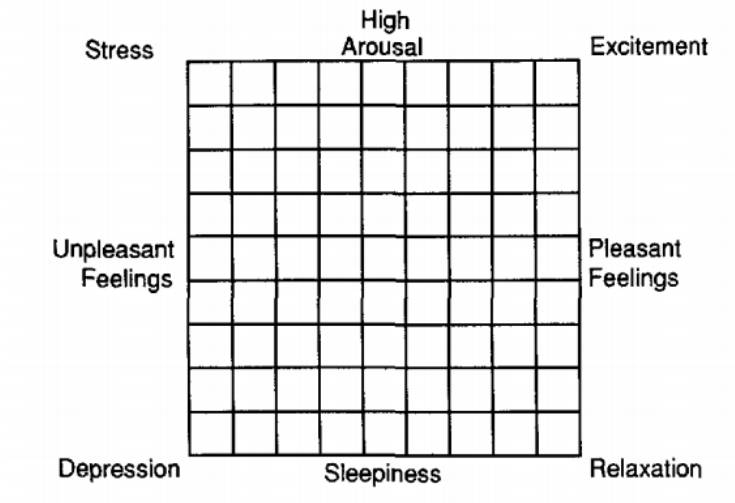


Figure 2: Various states in the Affect Grid. This enables us to quantify the emotional state of the subject during the different stages of the experiment

4. RESULTS

4.1 Affect Grid Questionnaire

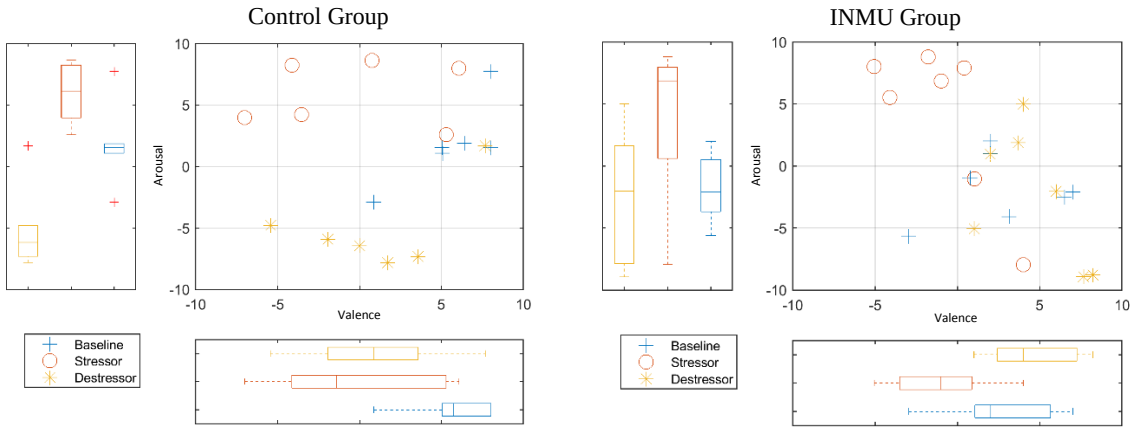
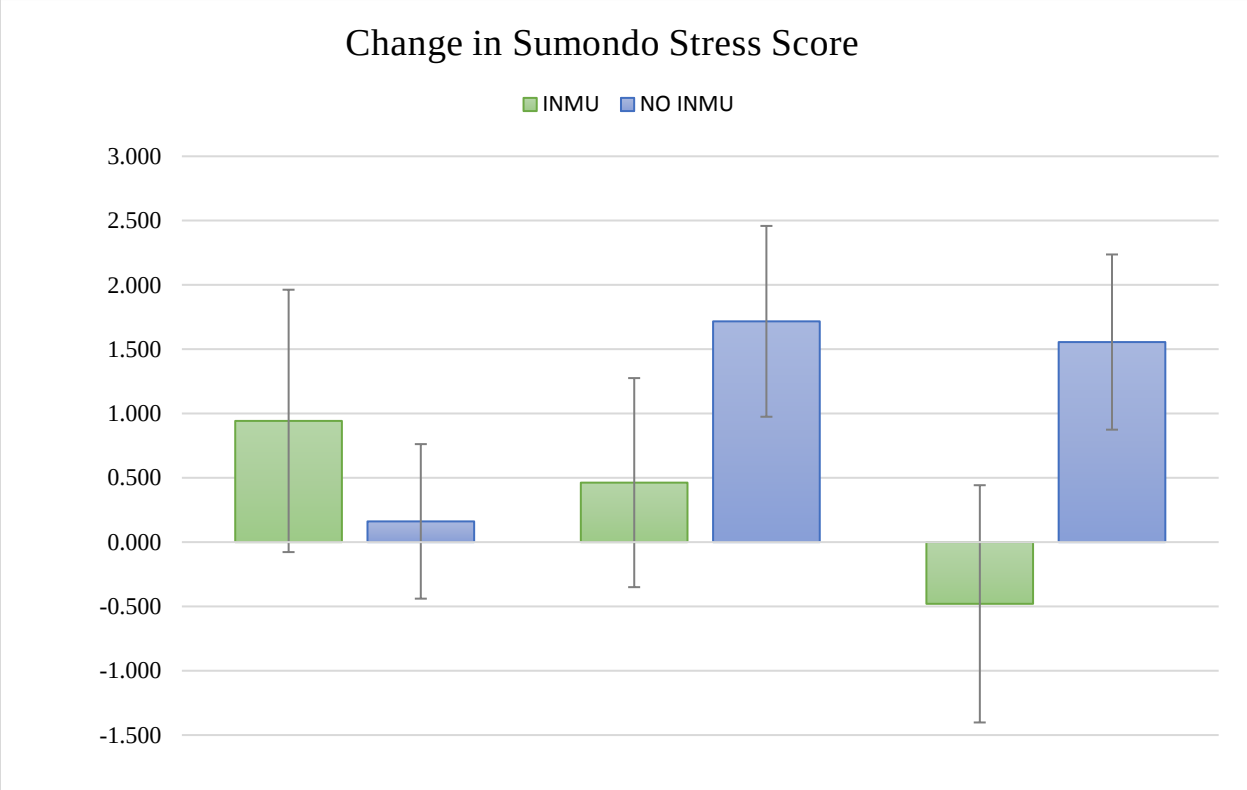


Figure 3: Affect Grid Results for the Control and INMU Groups.

The negative to positive emotional transition (negative to positive on the valence axis of the affect grid) when moving from stressor to destressor in the INMU group is significant at p-val 0.009 with a jump of -0.925 to 4.657. Comparatively, the same transition for the control group is not significant at p-val of 0.341 for the transition of -0.4270 to 0.930. Along the arousal axis, a transition of high-arousal to low-arousal is observed in both groups with 4.0145to -2.431 (p-val 0.045) for INMU and 5.940 to -5.091 (p-val 0.002) for the control group. This shows that for the control group there is a significant decrease in arousal during the destressing period with a valence state which cannot be distinguished from the stressing period. For the INMU group there is also a significant decrease in arousal but with a valence state which is significantly more positive than the stressor period. Furthermore a significant decrease in valence is observed in the destressor period compared to the baseline period for the control group 5.565 to -0.430 (p-val=0.002). Comparatively the destressor valence of the INMU group shows no statistical difference from their baseline state. This suggests that, in contrast to the INMU group, the control group are not able to reach their previous level of positive valence during their destressing period.

4.2 Sumondo Stress Score

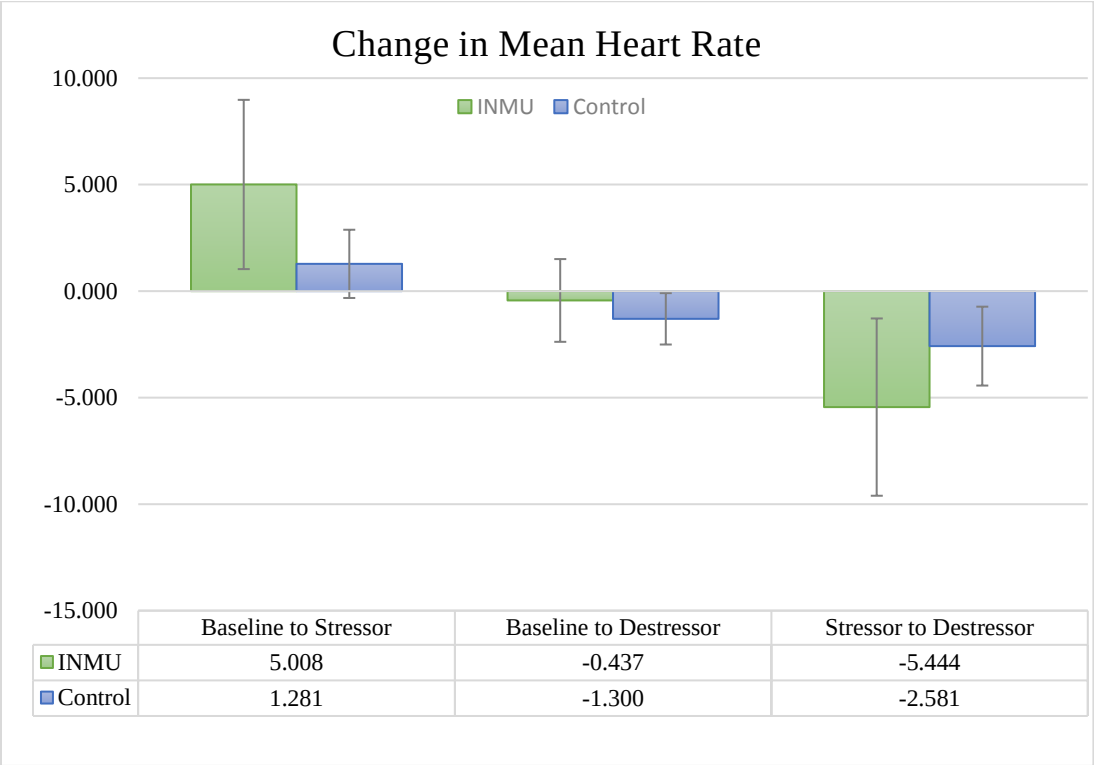


	Baseline->Stress	Baseline-> Destress	Stress->Destress
INMU	0.943	0.463	-0.480
NO INMU	0.161	1.717	1.556

Figure 4: Changes in the average Sumondo Stress Score for the INMU group in green and the Control group in Blue. Values shown are the mean of all subjects within that group and error bars show the standard error of that mean. Negative values indicate a reduction in stress from the previous state.

A decrease in the mean Sumondo stress score of -0.480 is observed for the INMU group when in the destressor state, compared to the stressor state. Adversely, for the control group, the stress score increases further to a mean of 1.556. This higher reduction of stress score for the INMU subjects compared to the control group is significant at p-val of 0.046. Additionally, 50% of the subjects in the INMU group saw a reduction in their stress score compared to 22% in the control group. For these subjects which were able to show a reduction in stress score in both groups, the mean reduction for the INMU group was higher than the control group -2.625 vs to -0.9 (p-val =0.082). This suggests again that for those who destressed in both groups, the destressing ability as described by the decrease in Sumondo stress score, is more pronounced for the INMU group.

4.3 Heart Rate through PPG measurements

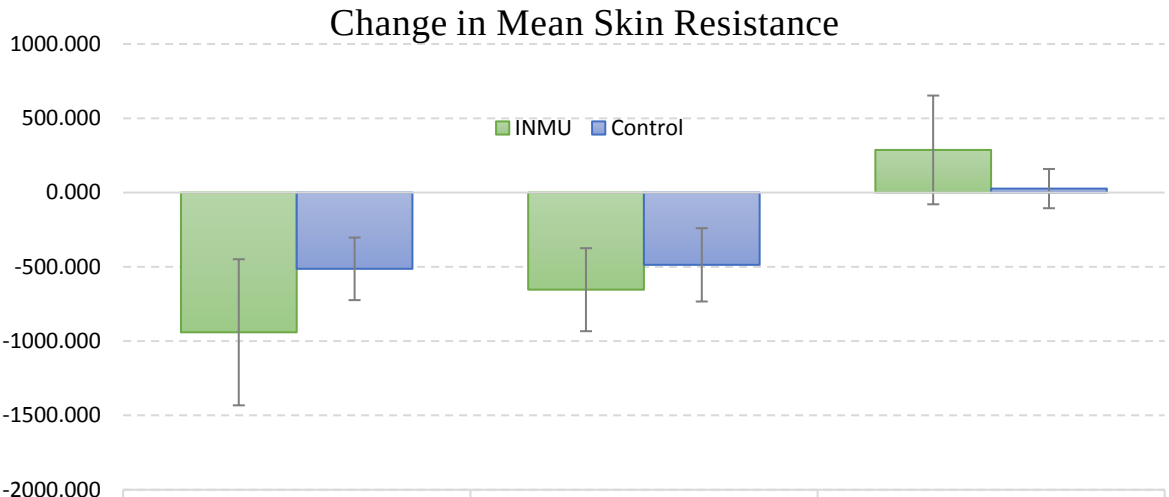


	Baseline to Stressor	Baseline to Destressor	Stressor to Destressor
INMU	5.008	-0.437	-5.444
Control	1.281	-1.300	-2.581

Figure 5: Changes in the average heart rate for the INMU group in green and the Control group in Blue. Values shown are the mean of all subjects within that group and error bars show the standard error of that mean. Negative values indicate a reduction in stress from the previous state.

Calculation of changes from the stressor to the destressor state show that the INMU destressing group had greater reduction in heart rate compared to the control group (-5.44 vs -2.581 p=0.285). 71.4% of the patients in the INMU group had a decrease in heart rate from stressor to destressor compared to 66.7% in the control group. In addition, for those subjects in the control group who upon moving from stressor to destressor had a reduction in mean heart rate, the reduction strength (-5.122) was lower to that of those in the INMU group (–9.727). The effects of low sample size are observed in the change in heart rate from baseline to stressor for both groups. Namely, with a large enough sample size we would expect the change for both groups to be similar as both the baseline and stressor conditions are identical for both groups. Even though there is a greater reduction in the average heart rate for the INMU group when moving from stressor to destressor state, compared to the control group, with a p-value of 0.285, the low sample size does not enable us classify the change as significant at a 5% significance level using a one-tailed unpaired Student's T-Test.

4.4 Skin Resistance through GSR measurements



	Baseline to Stressor	Baseline to Destressor	Stressor to Destressor
INMU	-940.357	-653.471	286.886
Control	-513.167	-486.483	26.683

Figure 6: Changes in the average skin resistance for the INMU group in green and the Control group in Blue. Values shown are the mean of all subjects within that group and error bars show the standard error of that mean. Positive values indicate a reduction in stress from the previous state.

Calculation of changes from the stressor to the destressor state show that the INMU destressing group had a greater increase in skin resistance compared to the control group (286.886 vs 26.683 p-val=0.272). 43% of the patients in the INMU group had an increase in mean skin resistance from stressor to destressor compared to 33% in the control group. Similar to the heart rate case, the subjects in the control group, who upon moving from stressor to destressor, had an increase in mean skin resistance, the increase (26.683) was lower to that of those in the INMU group (286.886). This suggests again that for those who destressed in both groups, the destressing ability as described by the increase in skin resistance, is more pronounced for the INMU group. With this in mind, this result is heavily affected by the large increase achieved by subject04 in the INMU group. Similarly to the heart rate, with a p-val of 0.272, the low sample size does not enable us classify the larger increase in mean skin resistance for the INMU group (compared to the control group) as significant at a 5% significance level.

4.5 HR and SRL Trajectories during destressor

The trajectories of the heart rate and skin resistance were analyzed for the 15-minute destressing interval for both groups. For both measurements, the mean value was calculated at intervals of one minute and the change relative to the mean measurement value during the stressor was recorded. This enables us to observe how the destressing as described by these physiological measurements changes in time.

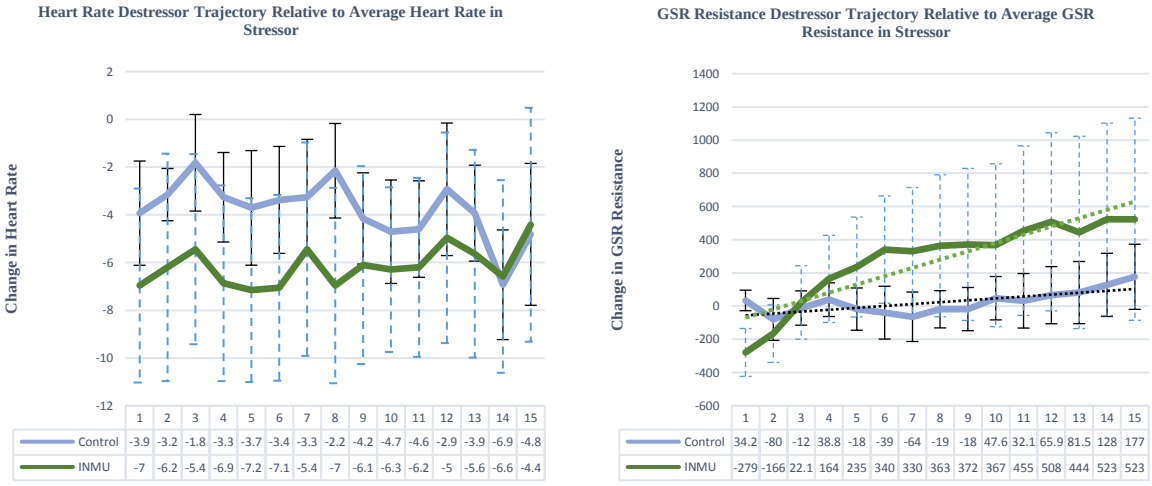


Figure 7: Trajectories of HR (left) and SRL (right) for the entire destressing period for the INMU (green) and Control (blue) groups. Measurements were averaged over 1 minute time-windows and changes within this window were calculated with respect to the average level in the previous stressor state.

From the heart rate trajectories it is observed that both groups have the largest drop in heart-rate by the first minute of the destressing period. The reduction is on average sustained throughout the 15 minute interval. For the control group, it is only after the 13 minute that the heart rate approached levels similar to the ones in the INMU group. For the skin resistance trajectories, the INMU group shows a continuous increase in skin resistance throughout the 15 minute interval, with a change of 600 units by the first 6 minutes. For the control group, the trajectory is more flat and only starts to increase slightly after the 12 minute mark but still does not reach levels high as the INMU group. As confirmed by the linear trend lines, this shows that as described by the skin resistance, the INMU group are destressing at a higher rate than the control group.

5. CONCLUSIONS

The destressing ability as described by physiological measurements and the Sumondo stress score has been assessed for the INMU device compared to a control group. Subjects enrolled in an experiment which their heart rate, skin resistance and Sumondo stress score was measured. This alongside with their answers to a number of questions describing their then present emotional state. This was done in three specific periods described as the Baseline period, the Stressor period and the Destressor period. For the INMU and the control group, the only difference was the latter period, in which the INMU group had the INMU device with music interaction whereas the control group had no music or device to destress with.

- Qualitative questions shows a statistically significant increase in positive valence for the INMU group in the destressor period compared to the stressor period. This could not be shown for the control group. Additionally the INMU group were able to achieve positive valence levels statistically similar to their baseline levels, something which was not achieved by the control group. This shows that qualitatively, the subjects using INMU device for the destressing, exhibited a more positive emotion, one which was akin to their pre-stressed state. This was not achieved by the control group.
- Using the three physiological measurements (Sumondo stress score, heart rate and skin resistance) as independent surrogates to stress levels, it was separately shown for each of the 3 measurements that:
    - The mean stress reduction in the INMU group was greater than the control group when destressing. The reduction was found to be significant for the Sumondo Stress Score.
    - The percentage of patients which were able to destress was greater in the INMU group than in the control group.
    - For the subjects who were able to destress in the control group, the destressing magnitude was still lower than those subjects that destressed in the INMU group.
- Trajectories of the heart rate and skin resistance during the 15 minute destressing period were also analyzed for both groups. An immediate reduction in heart rate in both groups was observed, which was higher for the INMU group and then sustained for both groups. For the skin resistance, the INMU group exhibited a rate of destressing greater to that of the control group.

As described by qualitative questions and physiological measurements related to stress reduction, it could be shown that music interaction using the INMU device exhibits several stress reducing properties. The caveat to this is that the low sample size did not enable all such exhibitions to be statistically significant. With this in mind, the reduction in stress, as described by separate stress indicators, was consistent across the indicators tested. Given these initial positive findings, further research in Phase 2 may now focus on:

- **Defining an accurate measure of stress through Machine Learning**: For a sound assessment of stress reduction, one needs to have a means to quantify stress accurately. In phase 1 a number of stress

indicators were analyzed for their changes between condition groups. Phase 2 will in turn combine all stress indicators into one single and more robust stress score. This will be done through a machine learning protocol which analyzes several features from the respective physiological measurements. This will also enable the validation of the Sumondo device in its ability to quantify changes in stress.

- **Quantifying the effect of adaptive sound in stress reduction:** Given the limited sample size in phase 1, the effect of music interaction could only be compared against a single control. Given the positive findings of this single control experiment, in phase 2, several controls will be added in order to assess to which extent the interaction in sound (as opposed to non-adaptive music) itself is affecting the destressing ability. In addition, the results from such additional controls can be used for further optimization of the INMU music device.

Critical to the success of phase 2 is the sufficient recruitment of participants. This would be necessary for the addition of more controls; to analyze results separately for subjects with varying music absorption scores; to analyze results separately for subjects with varying levels of interaction when using the INMU device; and to increase the power of the statistical testing when assessing changes in stress levels between condition groups. By the end of phase 2, the expectation is to therefore have:

I. A single stress-score designed through machine learning which encompasses features from several stress indicators.
II. A quantification of the role of adaptive music vs non-adaptive music in stress-reduction.
III. Insights for the design of future music intervention systems for stress reduction.

6. SUPPLEMENTARY DATA

6.1 Mean Heart Rate extracted from the PPG for INMU and Control Groups

Subject	*Mean Baseline*	*Stdev Baseline*	*Mean Stressor*	*Stdev Stressor*	*Mean Destressor*	*Stdev Destressor*	*Baseline to Stressor*	*Baseline to Destressor*	*Stressor to Destressor*
01INMU	70.2105	1.6186	71.2632	1.9103	77.3	4.8548	1.0527	7.0895	6.0368
02INMU	76.8421	2.0348	90.5263	5.0262	73.4667	1.9438	13.6842	-3.3754	-17.0596
03INMU	68.1053	1.9406	91.8947	2.9419	68.1429	2.9259	23.7894	0.0376	-23.7518
04INMU	73.3684	3.1307	77.5789	1.8353	73.9333	3.1883	4.2105	0.5649	-3.6456
05INMU	70.5263	6.4581	63.5789	1.2612	60.7797	3.6392	-6.9474	-9.7466	-2.7992
06INMU	71.5789	2.3645	74.2105	2.3939	72.8333	2.8592	2.6316	1.2544	-1.3772
07INMU	75.0526	2.3446	71.6842	2.3346	76.1695	2.7364	-3.3684	1.1169	4.4853

Subject	*Mean Baseline*	*Stdev Baseline*	*Mean Baseline*	*Stdev Stressor*	*Mean Destressor*	*Stdev Destressor*	*Baseline to Stressor*	*Baseline to Destressor*	*Stressor to Destressor*
01Control	67.5789	2.6313	69.0526	1.3934	68.0333	3.9573	1.4737	0.4544	-1.0193
02Control	79.4737	2.7359	81.6842	2.1357	77.3667	2.864	2.2105	-2.107	-4.3175
03Control	67.8947	2.2582	64.8421	1.214	65.1667	3.9538	-3.0526	-2.728	0.3246
04Control	62.7368	2.5131	60.9474	1.026	65.6271	3.9036	-1.7894	2.8903	4.6797
05Control	70.7368	2.8449	79.6842	2.5178	70.8	3.2977	8.9474	0.0632	-8.8842
06Control	97.4737	2.816	97.3684	3.2009	91.1	2.5624	-0.1053	-6.3737	-6.2684

6.2 Skin Resistance extracted from the GSR for INMU and Control Groups

Subject	*Mean Baseline*	*Stdev Baseline*	*Mean Stressor*	*Stdev Stressor*	*Mean Destressor*	*Stdev Destressor*	*Baseline to Stressor*	*Baseline to Destressor*	*Stressor to Destressor*
01INMU	1795.8	125.3159	1588.1	40.2745	954	419.9	-207.7	-841.8	-634.1
02INMU	740.9	96.5146	665	38.7859	535.8	102.4	-75.9	-205.1	-129.2
03INMU	2406.2	511.3021	972.7	96.4275	742.3	161.2	-1433.5	-1663.9	-230.4
04INMU	4061.2	96.3439	367.9	154.1555	2618.1	903	-3693.3	-1443.1	2250.2
05INMU	2662.9	415.1421	2359.8	499.2762	3147.1	1220.1	-303.1	484.2	787.3
06INMU	1936.3	63.0958	1754.5	128.1611	1585.7	271.2	-181.8	-350.6	-168.8
07INMU	1617.7	236.3343	930.5	117.2386	1063.7	170.7	-687.2	-554	133.2

Subject	*Mean Baseline*	*Stdev Baseline*	*Mean Baseline*	*Stdev Stressor*	*Mean Destressor*	*Stdev Destressor*	*Baseline to Stressor*	*Baseline to Destressor*	*Stressor to Destressor*
01Control	3245	342.5388	1858.8	138.8836	1756.6	247.3884	-1386.2	-1488.4	-102.2
02Control	1225.8	88.6266	1400	8.6875	1449.3	49.3008	174.2	223.5	49.3
03Control	3460.3	131.1442	2911.7	77.1347	2728.8	58.5262	-548.6	-731.5	-182.9
04Control	1268.6	106.4796	600.7	51.106	1248.6	262.0528	-667.9	-20	647.9
05Control	488	98.1564	176.5	15.5227	172.2	21.1494	-311.5	-315.8	-4.3
06Control	1983.8	456.2074	1644.8	272.6239	1397.1	186.3624	-339	-586.7	-247.7

6.3 Sumondo Stress score extracted from Sumondo device and app for INMU and Control Groups

Subject	*Mean Baseline*	*Mean Baseline*	*Mean Destressor*	*Interaction with INMU*	*Baseline to Stressor*	*Baseline to Destressor*	*Stressor to Destressor*
01-INMU	8.5	8.44	11.9	Mixed Use	-0.06	3.4	3.46
*02-CONTROL**	5.7	5.6	6.6		-0.1	0.9	1
03-CONTROL	6.65	7.7	13.2		1.05	6.55	5.5
04-INMU	5.5	9.9	6.6	Mixed Use	4.4	1.1	-3.3
*05-CONTROL**	4.85	5.4	6.5		0.55	1.65	1.1
06-CONTROL	3.1	3.3	6.5		0.2	3.4	3.2
*07-INMU**	4.4	6	5.2	Good	1.6	0.8	-0.8
08-INMU	12.05	7.9	9.4	Good	-4.15	-2.65	1.5
09-CONTROL	9.8	7.6	9.4		-2.2	-0.4	1.8
10-INMU	7.4	12.4	9.9	One Sound	5	2.5	-2.5
11-INMU	11.15	12.1	8.2	No Sound	0.95	-2.95	-3.9
12-CONTROL	6.9	3.9	6.6		-3	-0.3	2.7
13-CONTROL	6.6	7.7	8.2		1.1	1.6	0.5
14-INMU	3.9	4.2	5.7	Mixed Use	0.3	1.8	1.5
15-CONTROL	3.5	6.5	5.8		3	2.3	-0.7
16-CONTROL	4.25	5.1	4		0.85	-0.25	-1.1
17-INMU	7.8	7.3	7.5	Good	-0.5	-0.3	0.2

6.4 Valence and Activity states (Affect Grid) for INMU and Control Groups

	IINMU	*Valence*	*Activity*		*Control*	*Valence*	*Activity*
01INMU	Baseline	3.1328	-4.0788	01Control	Baseline	8.0234	1.519
01INMU	Stressor	1.0391	-1.0408	01Control	Stressor	-7.0078	3.9662
01INMU	Destressor	1.9922	0.9564	01Control	Destressor	7.6641	1.6878
02INMU	Baseline	0.7578	-0.9283	02Control	Baseline	6.3828	1.8565
02INMU	Stressor	-4.1016	5.5134	02Control	Stressor	0.7578	8.6357
02INMU	Destressor	7.6641	-8.9451	02Control	Destressor	1.7109	-7.82
03INMU	Baseline	-2.9609	-5.6259	03Control	Baseline	5.0703	1.0689
03INMU	Stressor	-1.7734	8.8045	03Control	Stressor	6.0703	7.9887
03INMU	Destressor	3.6953	1.8565	03Control	Destressor	-1.9297	-5.9072
04INMU	Baseline	2.0078	1.9972	04Control	Baseline	5.0234	1.5471
04INMU	Stressor	4.0078	-7.9606	04Control	Stressor	-4.1328	8.2419
04INMU	Destressor	6.0078	-2.0253	04Control	Destressor	0.0078	-6.4416
05INMU	Baseline	7.0078	-2.0816	05Control	Baseline	0.8672	-2.8973
05INMU	Stressor	-5.0547	8.0169	05Control	Stressor	-3.5547	4.2194
05INMU	Destressor	4.0078	5.007	05Control	Destressor	-5.4453	-4.782
06INMU	Baseline	6.4922	-2.4754	06Control	Baseline	8.0234	7.7356
06INMU	Stressor	-0.9922	6.8636	06Control	Stressor	5.2891	2.5879

06INMU	Destressor	8.2266	-8.8045	06Control	Destressor	3.5703	-7.3136
07INMU	Baseline	1.9766	1.0127				
07INMU	Stressor	0.3984	7.9044				
07INMU	Destressor	1.0078	-5.0633				

REFERENCES:

[1] S.L. Carstensen, J. Madsen, J. Larsen. The Influence of Familiarity and Absorption on the Effectiveness of Music in Stress Reduction, in submission 2017. S. S. Dickerson and M. E.

[2] Kemeny, “Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research,” Psychological Bulletin, vol. 130, no. 3, pp. 355–391, 2004.

[3] V. Sandulescu, S. Andrews, D. Ellis, N. Bellotto, and O.M. Mozos. Stress detection using wearable physiological sensors, IEEE Computer, vol. 48, no. 10, pp. 22–33, 2015.

[4] G. Pozo A. Sierra, C. Avila and J. Casanova. Stress detection by means of stress physiological template. Third world Congress on Nature and Biologically Inspired Computing, pp. 131–136, 2011.

[5] R. Sioni and L. Chittaro. Stress detection using physiological sensors. IEEE Computer, 48(10), pp. 26-33, 2015.

[6] A. Burns *et al*., "SHIMMER™ – A Wireless Sensor Platform for Noninvasive Biomedical Research," in *IEEE Sensors Journal*, vol. 10, no. 9, pp. 1527-1534, Sept. 2010.doi: 10.1109/JSEN.2010.2045498

[7] Percy D. Peckham Gene V. Glass and James R. Sanders. Consequences of failure to meet assumptions underlying the fixed effects analyses of variance and covariance. Review of educational research, 42(3):237–288, 1972.

[8] J. A. Russell, A. Weiss, and G. A. Mendelshohn, “Affect grid: A single-item scale of pleasure and arousal,” Journal of personlaity and social psychology, vol. 57, no. 3, pp. 493–502, 1989.

[9] G. M. Sandstrom and F. A. Russo, “Absorption in music: Development of a scale to identify individuals with strong emotional responses to music,” Psychology of Music, vol. 41, no. 2, pp. 216–228, 2013.