

# Summary of X-System Experiment Analysis report

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The following presents a headline summary of empirical research findings from a detailed preliminary report by Dr. Agres, *X-System Experiment Analysis Report*, presented to the CEO of X-System on November 1st, 2016.

## 1 The status of the report and the summary

This report is a review of initial findings for a study that will not be completed until December 2016. The study as a whole is designed to capture both autonomic (heart rate) and endocrine data (cortisol, cortisone, progesterone, testosterone, Dehydroepiandrosterone and possibly estradiol) for participants responding to entrainment playlists generated by X-System, designed either to relax or to enliven the listener.

There are a number of caveats and considerations with the current dataset. Firstly, around 20% of the autonomic data collected for the experiment have yet to be processed and prepared for data analysis. Secondly, as with many studies examining autonomic responses, these data are noisy. In addition, some segments of data failed to be properly stored as a result of an early software bug. Therefore, for this preliminary analysis, only participants with complete and reliable playlist data were included. Thirdly, the experiment was designed to be able to capture endocrine data from saliva samples. This meant that playlists were of approximately 45 minutes duration - the advised time lapse for detection of endocrine activity in saliva - as opposed to the approximately 20 minutes duration normal for the achievement of autonomic entrainment; weaknesses must therefore be expected in the autonomic data. Finally, because of the time required to send the saliva samples away for laboratory testing, the endocrine results will not be available until December.

## 2 Design

- Participants listened via headphones to two playlists, each of approximately 45 minutes' duration, generated by X-System. One was intended to entrain listeners, step by step, to enlivenment, the other to entrain listeners to relaxation.
- Every participant listened to both of the entrainment playlists, and the order of playlists was counterbalanced across participants (i.e., some began with the Enliven playlist, others with the Relax playlist). Participants in the X condition heard the Enliven playlist first; those in the Y condition heard the Relax playlist first.
- The experimental participants (those listening to the two playlists) were compared to participants in control conditions (ZX and ZY), in which no music was heard (but all other experimental factors remained constant).
- A relaxation period of 10 minutes preceding the Enliven playlist, and a stressor activity (in this case, mathematical tests) preceding the Relax playlist.

- The State component of the State-Trait Anxiety Inventory questionnaire (STAI)\* was administered before and after each playlist to gauge the participants' subjective anxiety.
- Collection of saliva samples before and after each playlist.
- A pulse oximeter sensor to collect continuous heart rate data, as well as a dedicated phone app to record heart rate data.
- Two brief emotionally-neutral documentary films, each lasting the duration of the playlists.

### 3 Protocol

Participants were randomly assigned to condition X or Y. Baseline heart rate data were combined with STAI scores for each participant to determine which of five possible starting points in the playlists the participant would begin with. For example, participants in the low to high arousal (Enliven) playlist with low HR and anxiety scores began with the first track (corresponding to the track with lowest arousal), while participants with high scores would start at track 5 (corresponding to the starting track with highest arousal). This was in order to achieve a maximum entrainment effect. Figure 1 visualizes the details of the experimental protocol.

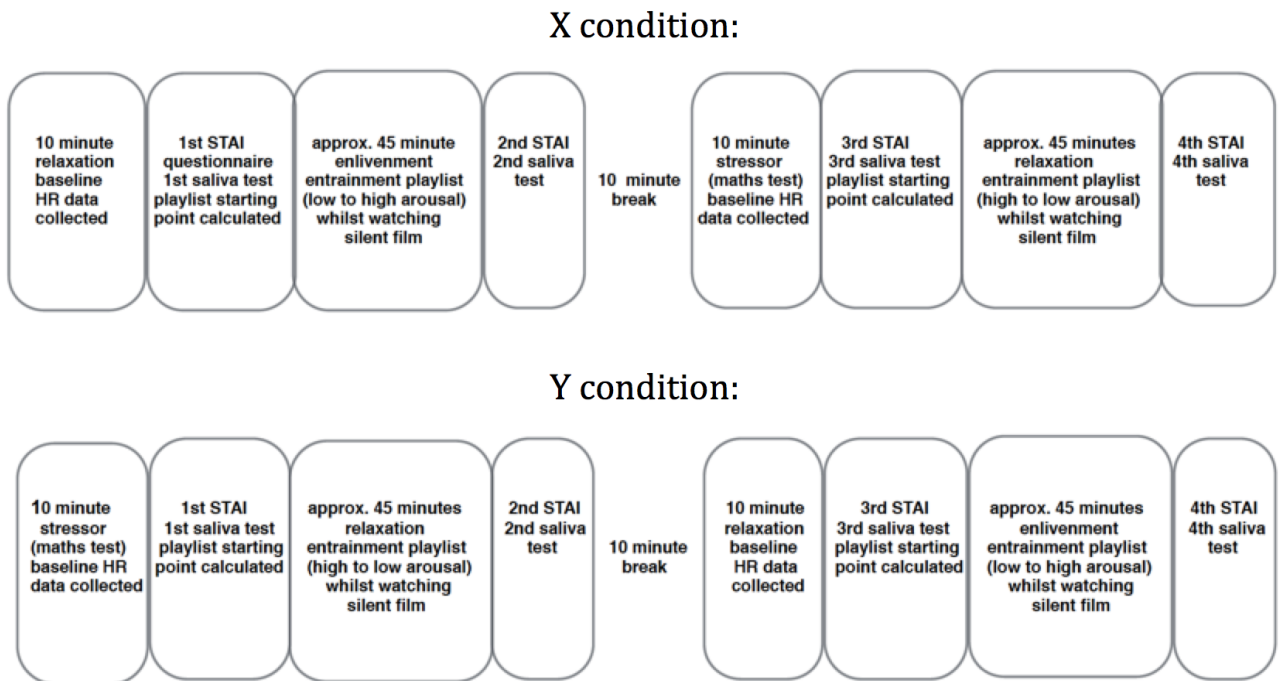


Figure 1: Experimental protocol

### 4 Hypothesis

**1.** The Relax playlists should show autonomic counterarousal (lower heart rate) and reduction in the release of stress-related hormones. **2.** The Enliven playlists should show increased autonomic arousal (higher heart rate) and increased levels of stress-related hormones. **3.** Data from the experimental playlists should show a significantly greater effect of entrainment than data from the control playlists.

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\*The S-Inventory collects Likert scale responses to statements such as “I feel calm”, “I feel jittery”, “I feel at ease” to score participants' levels of “in the moment” anxiety.

## 5 Preliminary results

### 5.1 Relaxation entrainment playlist (with some observations on enlivenment)

The preliminary results show that the X-System relaxation entrainment playlist successfully lowered the mean heart rate of listeners. Importantly, there were also significant differences between the experimental (music) and control (no music) conditions. The mean raw heart rate data for the Relax playlist shows a reduction in HR and “relaxation” effect:

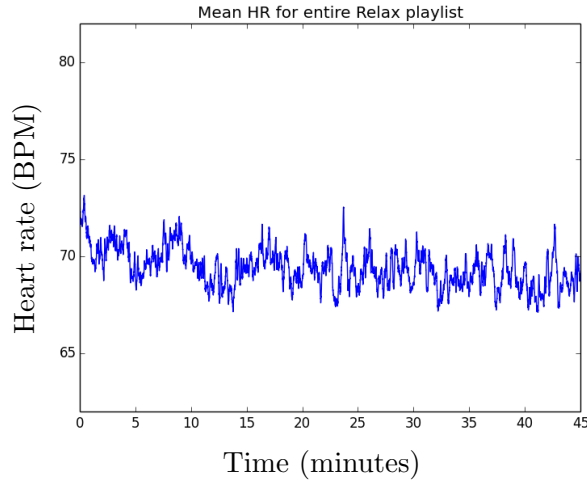


Figure 2: Mean HR data across Experimental (not Control) participants during the Relax playlist.

Comparing the raw HR data between the Relax playlist in condition Y and the “no music” control condition (ZY) shows an observable entrainment of reduction in heart rate for the Relax playlist (in red), whereas the control data has little apparent structure (see Figure 3).

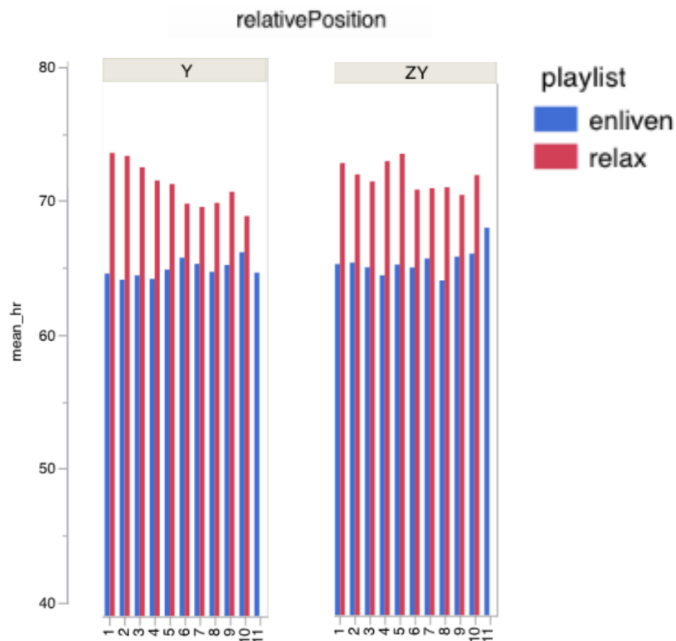


Figure 3: Comparison of Enliven and Relax playlists (across relative track positions) for conditions Y (experimental) and ZY (control)

Figure 3 represents the “relative” version of the playlist data, where track 1 corresponds to the first track a participant heard (note that there were five possible starting positions (tracks) within each playlist). The “absolute” version is where track 1 is simply the first track of the playlist (i.e., a participant may begin by listening to a track that has absolute position ‘3’). (The blue columns on the left represent the Enliven playlist HR for each track. Although there is a modest enlivenment effect, this was not significant in this analysis in either the experimental or control conditions).

The mean heart rate for “relative” track positions shows a clear downward trend of heart rate for the Relax playlist (in red, Figure 4a), and the effect is even clearer for “absolute” track positions (4b). (The Enliven playlist, represented by the blue columns below, shows little discernible effect in the relative track position graph (4a), but shows evidence for entrainment of increasing heart rate and arousal for absolute track positions in (4b).) This may be because the tracks at the very beginning and end of the playlists (corresponding to the first several and last several absolute positions) contain the most extreme musical features contributing to entrainment (e.g., tracks in Enliven positions 1 and 2 featured slow tempi and high harmonic, etc).

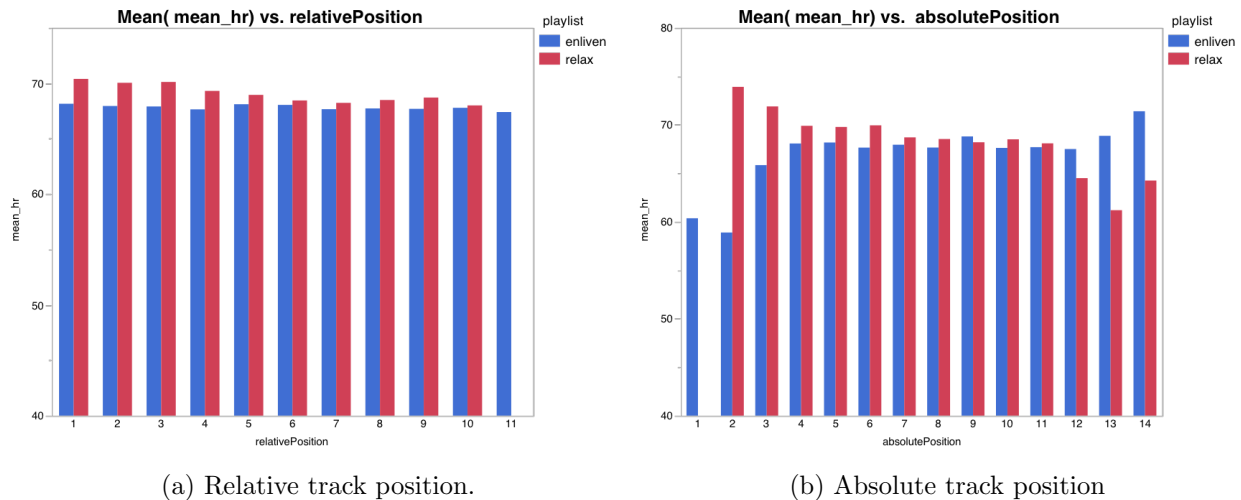


Figure 4: Mean HR (for Experimental participants) for every track according to the relative and absolute track positions, respectively, for the Enliven and Relax playlists.

Statistical analysis confirms these observations. For absolute track positions, there is a significant statistical contrast,  $F = 10.73, p < 0.001^*$ , between mean HRs for tracks 2-4 and 12-14 of the relaxation playlist, i.e. the heart rate at the end of the playlist is significantly lower than at the beginning of the playlist.

Other tests produced similar results. The Matched Pairs Test<sup>†</sup> shows a significant statistical difference ( $t = 2.35, p < 0.05$ ) between HR data for the first and last tracks of the relaxation playlist, whereas no significant difference is found between the first and last tracks for the control (no music) condition ( $t = 0.46, p = 0.65$ ). This shows that the playlist achieved significant relaxation, and that the equivalent condition without music did not. Similarly, a comparison between the first and last 200 datapoints (the equivalent of a little over one minute) of the relaxation playlist showed a significant difference ( $t = 3.30, p < 0.01$ ). The same comparison for the control (no music) group showed no significant difference ( $t = 1.32, p = .21$ ), again indicating that the observed decrease in HR was a result of the experimental Relax playlist.

In line with the results for the raw HR data cited above, the results for Z-scores<sup>‡</sup> for the relaxation

\*The F statistic is the ratio of variances within the group, and the  $p$  value is the probability of finding a result (test statistic) equal or greater than the observed result (scores below 0.05 are considered significant).

†The Matched Pairs T-Test is a calculation used when the data from the two groups can be presented in pairs, for example where the same people are being measured in before-and-after comparison.

‡The  $z$ -score quantifies how many standard deviations a data point is away from the population mean (of the partici-

playlist also indicate a reduction in heart rate, as displayed in Figure 5:

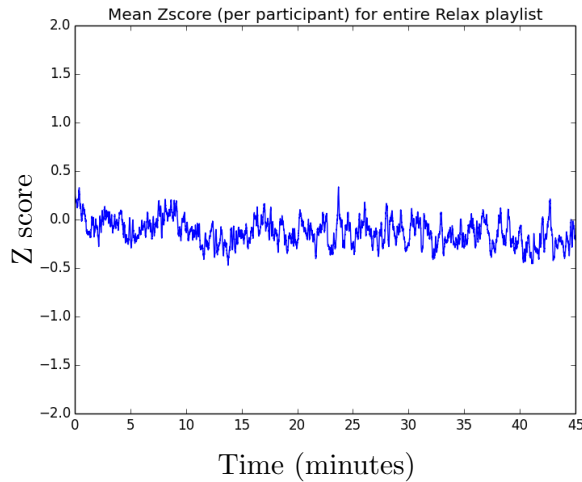


Figure 5: Average Z score for Experimental (X and Y) participants during the Relax playlist.

A comparison of Z-scores for the first and last 200 datapoints for the relaxation playlist showed a significant difference ( $t = 2.71, p < 0.01$ ), indicating once again that the heart rate at the end of the playlist was significantly lower than at the beginning. As with the other results, the same comparison for the control (no music) condition showed no significant difference ( $t = 1.07, p = .15$ ). Once again, this provides evidence that the playlist achieved a significant relaxation effect and that the condition without music did not.

## 5.2 Enlivenment entrainment playlist

The evidence for significantly raised heart rate for enlivenment playlists is, at this point in the experiment, much less compelling than for lowered heart rate in the relaxation playlists. It should be noted, however, that the accompanying activity (sitting and watching a documentary) during the enliven playlist and the corresponding control group was inherently relaxing. Therefore, the fact that the enliven playlist caused the mean HR to be higher than in the control group (see Figure 6) suggests that the vector of effect does function as predicted, even if a significant upward trend is not shown within the Enliven playlist itself. We predict that the Enliven playlist would have a greater effect if conducted during a less sedentary activity.

Despite a lack of supporting evidence for an increase in mean HR for the Enliven playlist using relative track positions, Figure 3b (above) indicates enlivenment entrainment (the blue columns) when considering the absolute position of tracks in the playlist. The contrast between tracks 2-4 and tracks 12-14 (absolute position) for the Enliven playlist is significant,  $F = 4.881, p < 0.05$ . These results show that the beginning of the enlivenment playlist (tracks 2 to 4)\* has a statistically significantly lower average HR than the end of the enlivenment playlist (tracks 12 to 14).

For the moment, however, the main conclusion is that the Enliven playlist has a stabilising, “maintaining state” effect. The comparison between the experimental (right hand graph) and control (left hand graph) below shows a clear relaxation entrainment (in red) from the experimental participants, but no entrainment in the controls. The Enliven playlist shows a similarly inchoate structure for the control participants, but those for the experimental participants (blue bars in the right hand graph) are far more level and consistent, if lacking specific entrainment, instead having a maintaining effect on listeners.

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pant), which provides a useful metric for analyzing the fluctuations in HR for each participant over time.

\*Note that track 1 was not chosen for the Absolute playlist because very few participants started with this track.

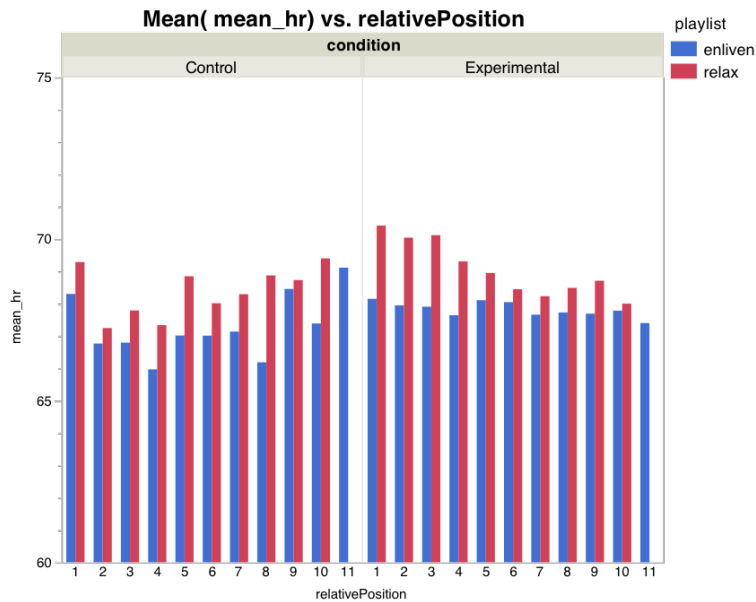


Figure 6: Mean HR for both playlists, using relative track position, comparing Experimental (X, Y) and Control (ZX, ZY) conditions.

It is likely that the 20 minute threshold for autonomic activation has had an effect on enlivenment results. Future analyses of the data will compare datapoints at the beginning of the playlist with datapoints 15-20 minutes into the playlist. Endocrine results may also be useful indicators of enlivenment entrainment.

## 6 Conclusion

X-System’s relaxation playlist significantly reduces heart rate. This finding emerged across numerous statistical tests, and the effect is significantly greater for participants who heard the Relax playlist than those who heard no music. There is some statistically significant evidence that the Enliven playlists increase heart rate, or serve to ‘maintain’ and stabilize HR in comparison with the control participants, but this finding is less compelling overall than for relaxation playlists.