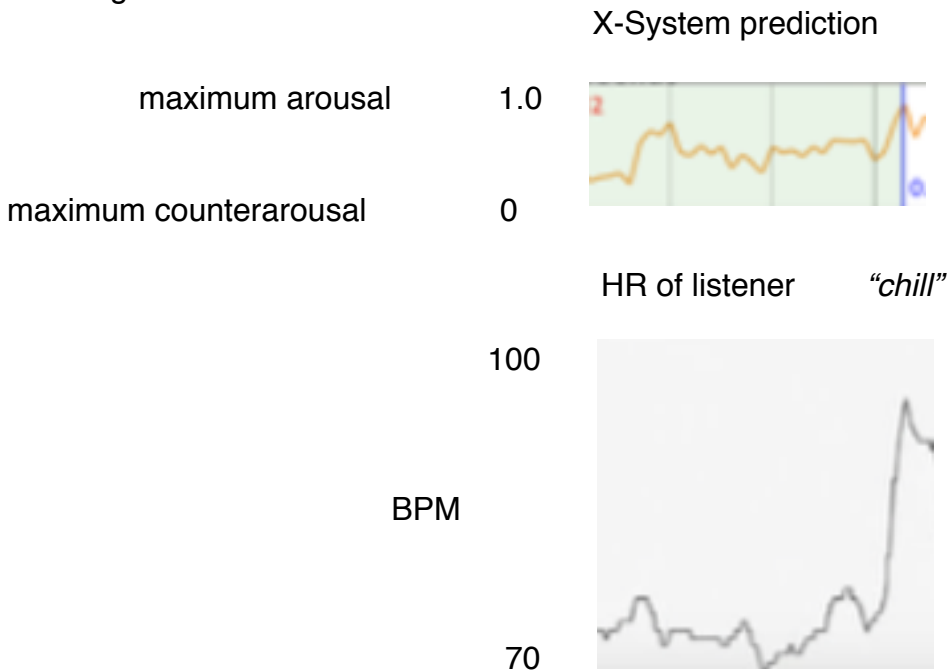


X-System Experimental Overview

1. Early anecdotal evidence

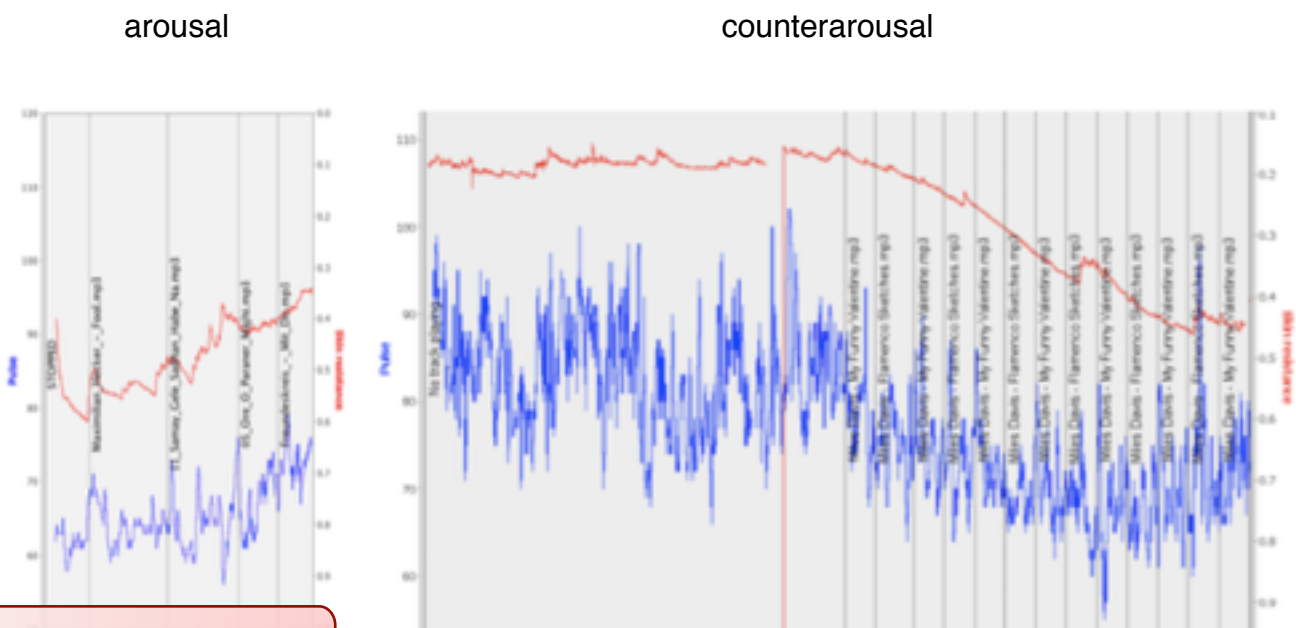
1.1 Moment-by-moment neurophysiological response

Early informal testing convinced the development team that **X-System could predict neurophysiological responses to music**. For example, the figure below shows X-System's prediction of neurophysiological response to a well-known musical "chill" - at the enharmonic and metrical change 2 minutes into Gustav Holst's *Venus* - and the heart rate of a single listener.



1.2 Entrainment of neurophysiological response

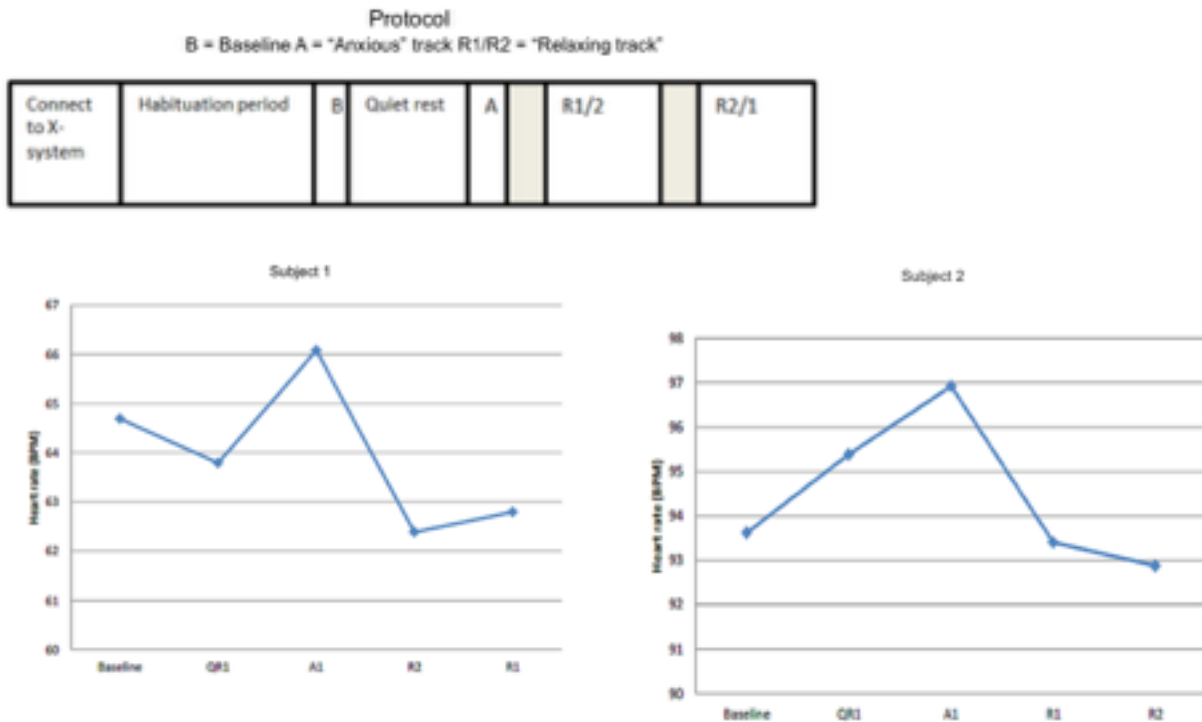
Numerous informal tests showed that **X-System could stream tracks to change the neurophysiological state of individual listeners step-by-step, track-by-track, e.g.**



2. Early experiments

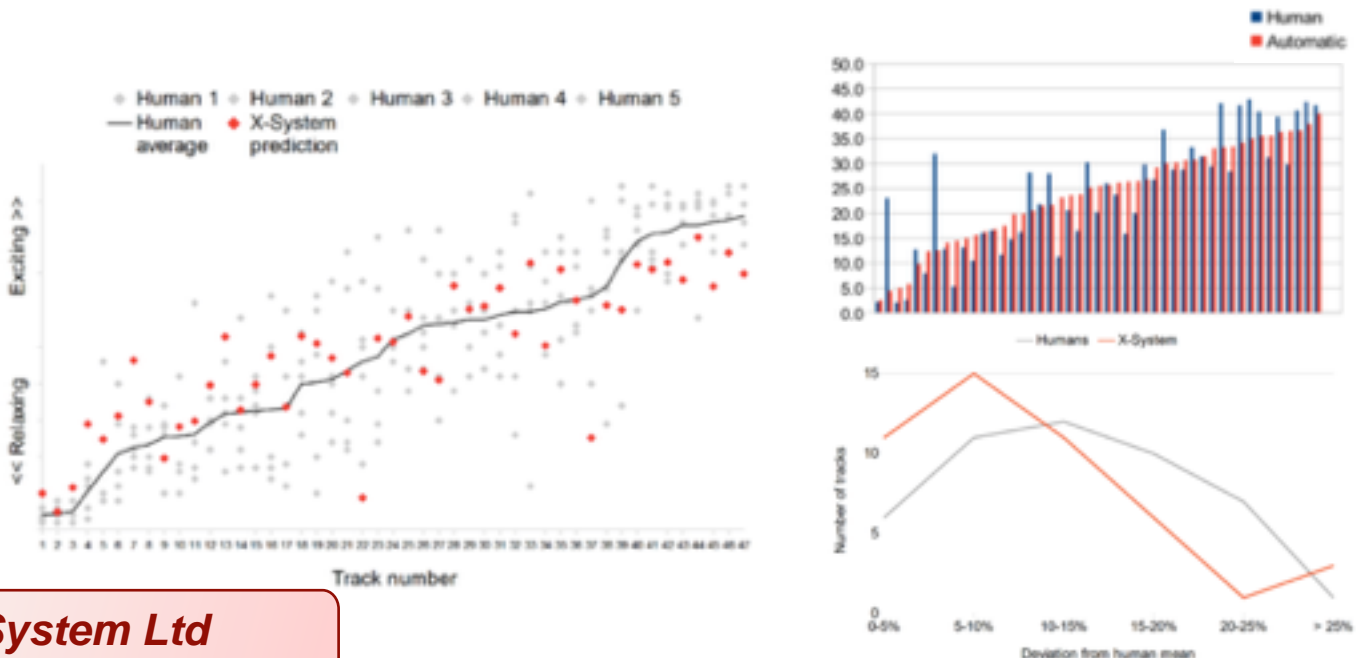
2.1 Anxiety reduction

A study was carried out under the supervision of Dr Matthias Schwannauer, Head of Health and Clinical Psychology, University of Edinburgh. X-System was used to select a stressor (A) and two relaxation tracks (R) for two subjects. **X-System playlists successfully induced stress and then reduced indicators of stress in two subjects**



2.2 X-System versus subjective categorisation

47 tracks were categorised in terms of arousal subjectively by 5 experts; the same tracks were predictively categorised by X-System. **X-System gave a better prediction of the mean of the outcome of the subjective analysis than any single expert.**



2.3 Testing the consistency of subjective categorisations

An intra-Class Correlation exercise was carried out among 16 experts listening to 100 tracks. This revealed both high levels, and a high degree of consistency among Intra-Class Correlation scores, ranging from 0.86 for turbulence to 0.95 for arousal and 0.97 for tempo.

3. Larger scale experiments

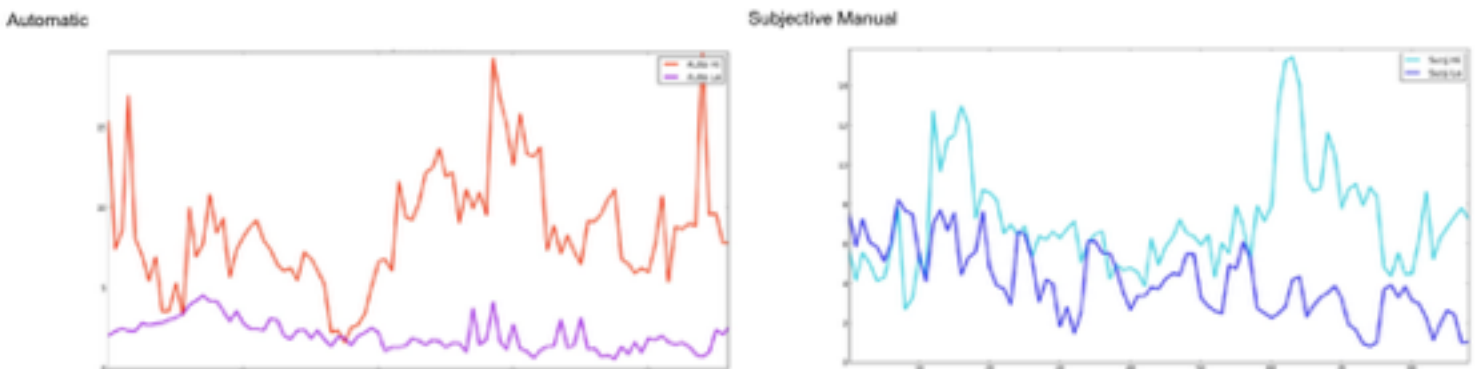
3.1 Moment-by-moment neurophysiological response

60 subjects listened to 31 tracks played in a randomised order, i.e. no entrainment. Moment-by-moment heart rate data was collected and compared with X-System moment-by-moment predictions for arousal. Dr Kat Agres of Queen Mary University found that **there was significant, positive cross-correlation between HR mean z-scores and X-System arousal prediction z-scores for 50% of data.** An important observation was that such correlations could appear at time lags of between 0 and 10 seconds.



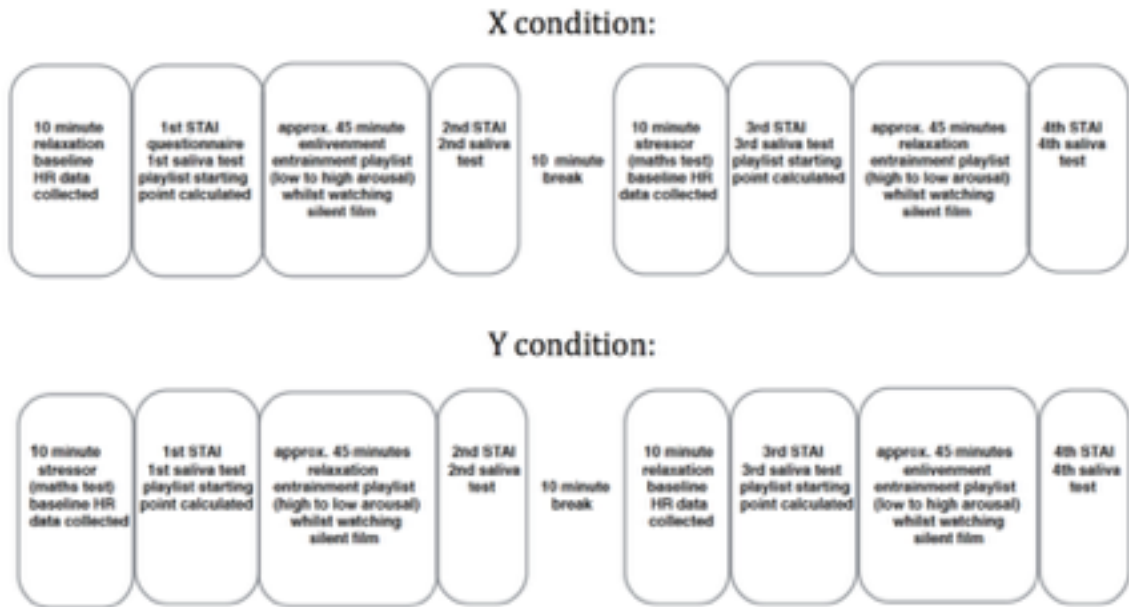
3.2 X-System versus subjective categorisation

60 subjects listened to 47 tracks. Skin conductance and heart rate data were normalised and combined. The data were split into bands of high, medium and low arousal. The first graph plots sensor data for X-System categorisations of tracks for high and low arousal. The second graph plots sensor data for subjective manual categorisation of the same repertoire. It is clear that the automatic categorisation achieves more accurate predictions and greater separation. **X-System may predict neurophysiological response more accurately than subjective categorisation.**

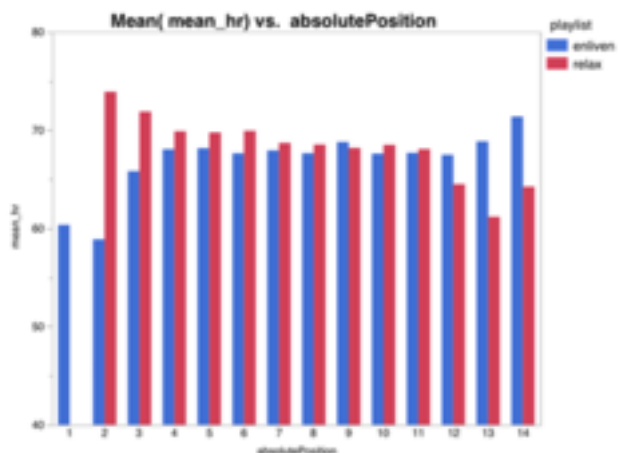
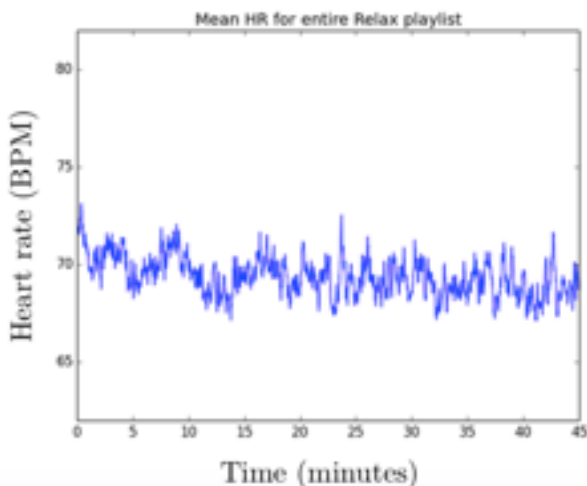


3.3 Entrainment of neurophysiological response - preliminary results

This study was led by Dr Kat Agres of Queen Mary University and Dr Daisy Fancourt of the Royal College of Music and Imperial College. There were 60 participants. The experiment included autonomic (HR), endocrine (cortisol, cortisone, progesterone, testosterone, dehydroepiandrosterone and possibly estradiol) and psychometric measures (STAI). The protocol embraced four conditions - the X and Y conditions below, including arousal and relaxation entrainments in alternate orders, and then the same two conditions without music, which were used as controls.



Preliminary results, so far restricted to autonomic data, show consistently strong evidence for the efficacy of X-System relaxation playlists, and good evidence for the enlivenment playlists. The graphs below show mean HR for the whole relaxation playlist (left), and a comparison of all enlivenment tracks (blue) and all relaxation tracks (red) in absolute order (right). (For entrainment purposes different participants started listening to the lists at different points). 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. The Enlivenment playlist also shows significant contrast between an initial relaxed state and enlivenment in the final tracks, $F = 4.881$, $p < 0.05$.



Further statistical tests revealed the following:

	relaxation playlist	control (no music)
Matched Pairs Test, comparison between first and last tracks	$t = 2.35, p < 0.05$ significant	$t = 0.46, p = 0.65$ not significant
Matched Pairs Test, comparison between first and last 200 datapoints	$t = 3.30, p < 0.01$ significant	$t = 1.32, p = 0.21$ not significant
Z-scores, comparison between first and last 200 datapoints	$t = 2.71, p < 0.01$ significant	$t = 1.07, p = 0.15$ not significant

The preliminary findings are that **X-System’s Relaxation playlists significantly reduce heart rate**. This finding emerged across numerous statistical tests, and **the effect is significantly greater for participants who heard the Relaxation playlist than those who heard no music**. There is some statistically significant evidence that the **Enlivenment playlists increase heart rate**, or serve to ‘maintain’ and stabilise HR in comparison with the control participants.

Nigel Osborne