Brain.fm

The Science

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Summary

- Brain.fm designs music to help you do things. Most music is optimized for how it sounds (aesthetics), but Brain.fm's music is also optimized for what it does (function).
    - Our various music-engines (A.I. systems) are each built to help the listener achieve desired different mental states, such as focus or sleep.

- Our 'focus' function has been very popular, and we recently won an National Science Foundation (NSF) grant to pursue this kind of music further.
- Initial results of this research suggest that:
    - Brain.fm 'focus' affects brain rhythms in the way we thought it would, promoting large-scale synchrony ('entrainment') much more than other music.
    - Brain.fm 'focus' reduces mind-wandering during task performance, compared to other backgrounds such as silence, noise, or other music.
    - The people with brain rhythms most affected by Brain.fm also have the most reduced mind-wandering. This suggests that, as intended, Brain.fm's unique effect on brain rhythms can influence performance on a task.
- Other functions such as 'sleep' are also producing exciting results. This work can be found at brain.fm/science (or in the attached supplementary materials), but is not detailed here.

We use music for all sorts of things: to help us study, to push us in a workout, or to get us to sleep, just to name a few. These functions probably weren't intended by the artist, but are useful side-effects of music that we recognize and utilize in our everyday lives. At Brain.fm we directly optimize music to target these functions. Guided by neuroscience and perceptual psychology, we develop hypotheses about what might be effective and test these hypotheses on a large scale to figure out what works.

Some desirable features of useful music are straightforward, such as not having vocals or sudden bursts of loud sound if you are trying to focus. But other less-obvious features seem to make a difference as well. One approach that appears successful is to deliver rapid amplitude modulations in the music (Fig.1) that are designed to alter neural oscillations (rhythmic activity in the brain). The ability to change brain rhythms in order to boost task performance has recently been demonstrated in the lab by others (e.g. Albouy et al. 2017, Neuron), but these methods require magnetic or electrical stimulation and are impractical for widespread use.

In contrast, music is easily delivered and enjoyable, and the possibility of similar performance-enhancing effects via auditory stimulation is apparent from the positive feedback of current users and from Brain.fm's success as a productivity tool to date. But the mechanisms behind such effects are not yet understood. Here we report on some of our ongoing work under an NSF (Technology-Transfer) grant awarded for this purpose.

The Music

All music contains amplitude modulation (quick changes in loudness), at many rates. Differences in amplitude modulation make sounds 'smooth' or 'rough', and are heard as aspects of timbre and sonic texture in music. Brain.fm's music-engine for 'focus' concentrates modulation energy at particular rates (Fig.1), to more dramatically change the listener's brain rhythms (Fig.2).

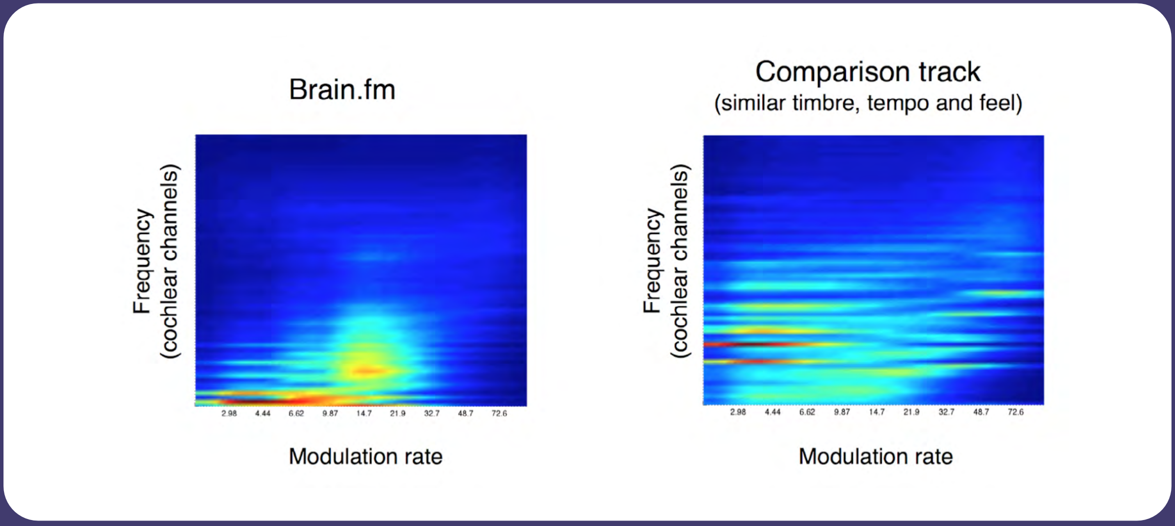

Figure 1.
Acoustic features unique to Brain.fm. The vertical axis on these plots depict frequency (0-20kHz). So, acoustic energy on the lower portion of both plots (warm colors) indicates that these tracks sound dark rather than bright, having little energy at high frequencies. The horizontal axis shows the amplitude modulation spectrum (amplitude fluctuations from 0-100Hz). Left panel: Modulation spectrum (averaged over time) of a typical Brain.fm track. Right panel: Modulation spectrum of a comparison track with similar timbre, tempo and feel. Modulation energy is concentrated in Brain.fm and distributed in the

comparison music. This is an unusual feature unique to Brain.fm, intended to have particular effects on the brain's rhythms. The results below (Fig.2) show that it has the effects intended.

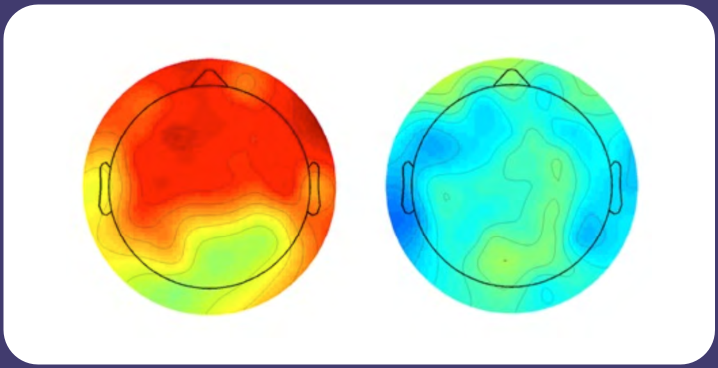

Figure 2.
Synchronized neural activity responding to Brain.fm versus Control Music. Red shows higher synchronized activity. Left: Brain.fm. Phase-locking values to amplitude modulation patterns in Brain.fm. Right: Control music. Same measurement for other music similar to Brain.fm but lacking particular modulation patterns, as depicted in Fig.1. Comparisons to noise and silence are not shown because the control music produced greater phase-locking than either.

The differences in acoustic modulation seen in Figure 1 appear in the brain as differences in synchronized neural activity in Figure 2. Brain.fm can thus be shown to produce very high levels of synchronized activity--and the music is designed to do just this, by having a predominant modulation rate. But will this process we see in the brain (called 'entrainment') have effects on task performance?

BEHAVIOR: How does Brain.fm ('Focus') affect performance?

We needed a standard task to evaluate 'focus', and chose the Sustained Attention to Response Task (SART), which is the current gold standard in evaluating mind-wandering behavior.
In this task, digits flash on screen one at a time, and the participant responds as quickly as

possible by a simple rule (e.g., hit a key if the number is not a '3'). At first their response-times will be similar from one trial to the next, but the task is pretty boring, and over the course of hundreds of trials (several minutes) responses times will increasingly vary as the participant's attention drifts in and out of the task.

We found that this mind-wandering behavior was reduced when listening to Brain.fm, compared to silence, noise, and other commercially-available music (this control music was chosen to be very similar in tempo and feel, but lacked some of the acoustic features introduced in Brain.fm to drive oscillatory activity).

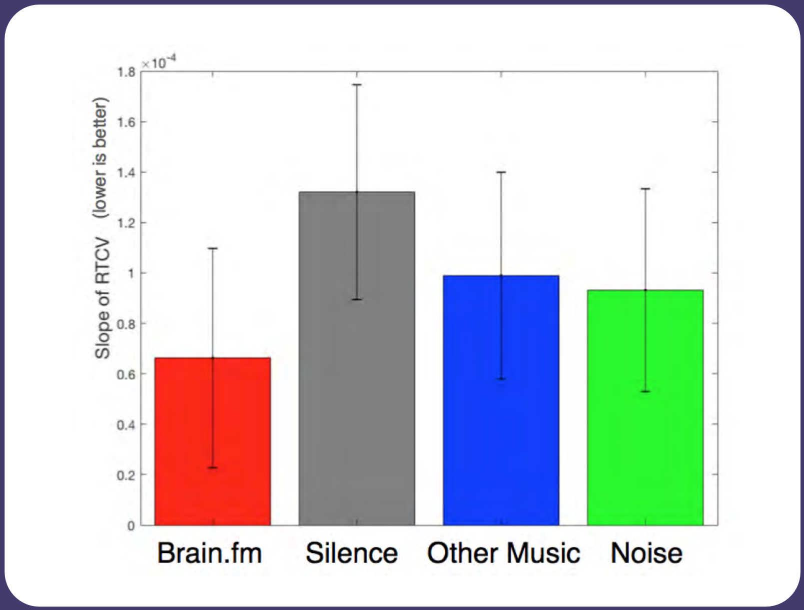

Figure 3.
Change in reaction-time variability ('mind-wandering') over ~10 minutes, under different background sounds. The y-axis depicts the slope of reaction time coefficient of variation (RTCV), taken over windows of 10 trials. Higher values indicate that reaction times became more variable over the course of the experiment, suggesting mind-wandering. Lower values indicate consistent response times (better). N=45. Errorbars depict +/-1 standard error of the mean.

This effect was encouraging, but we noticed that individual people could show very different patterns of performance under the different conditions. We split our participants into two groups, based on the comparison between their performance in Brain.fm versus silence; those with more consistent response times in silence (i.e., a lower slope of RTCV) are grouped as 'Brain.fm-ineffective' users for this analysis. The other participants showed more consistent responses in Brain.fm than in silence, and are grouped as ‘Brain.fm-effective’ users.

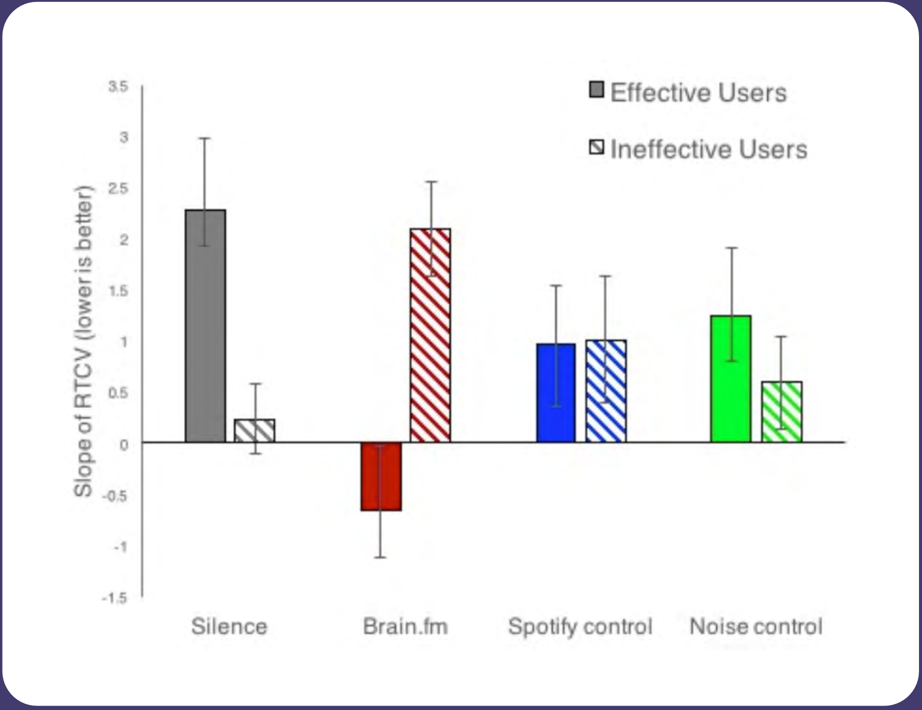

Figure 4.
Change in reaction-time variability (‘mind-wandering’), participants in two groups. Same data as the previous figure, with participants in groups: ‘Effective’ users (N=19 out of 45) had more consistent response times when listening to Brain.fm as compared to silence. Since the grouping was based only on the comparison to silence, the comparison between the resulting groups in the other conditions (Spotify, Noise) tells us that the Brain.fm-effective users were not better with any music or sound (instead, the benefit was specific to Brain.fm). N=45. Errorbars depict +/-1 standard error of the mean.

These groups of people were doing the same task and had the same sounds entering their ears, so how did they differ, that their performance would vary so widely due to the auditory background?

The brain's response to the music affects task performance

It turns out that if we place people into groups based on their task performance while listening to Brain.fm (as in the behavioral data above), we find large differences between these groups in how their brains respond to the music. This is remarkable because the groups are chosen solely based task performance; the group selection process is blind to the neuroimaging data.

Below on the left are the participants who became more consistent over time in the task while listening to Brain.fm; on the right are the participants who became less consistent in the task while listening to Brain.fm. Again, both groups were listening to Brain.fm and doing the same task.

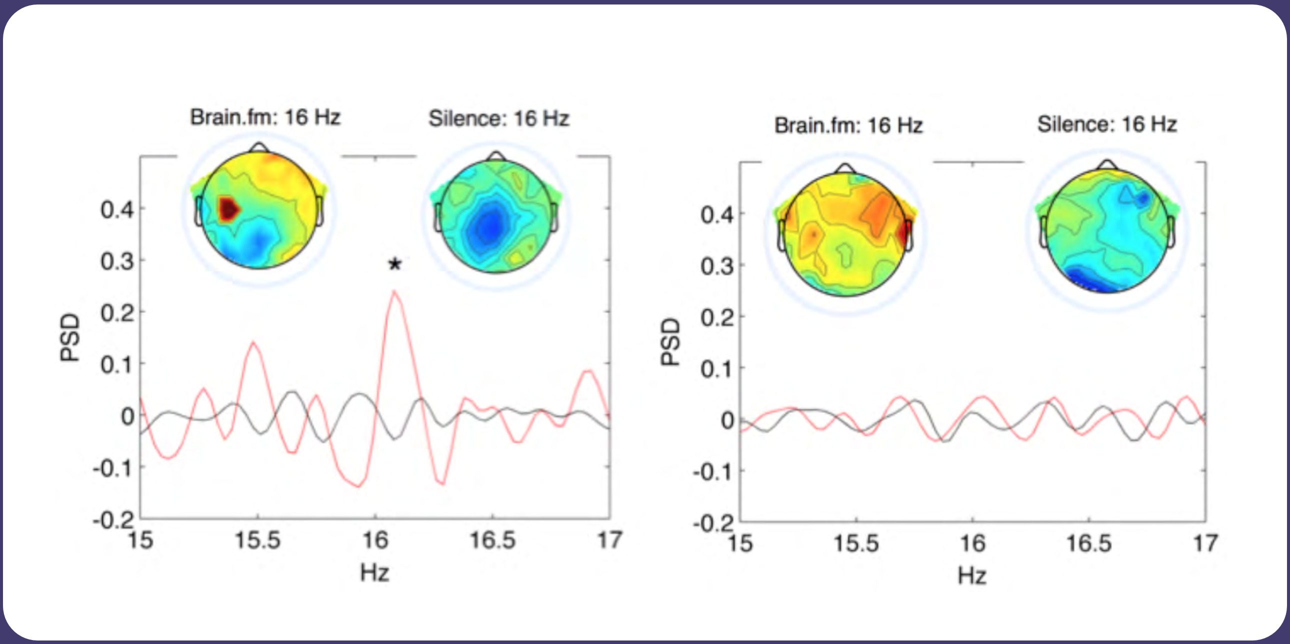

Figure 5.
EEG analysis. Participants in the left and right panels were grouped by task performance, looking only at their behavioral data. Plots depict Power Spectral Density (PSD) around the dominant modulation frequency in Brain.fm music, indicating the degree to which neural populations were fluctuating at the music's dominant rhythm. All participants were listening to the same music and doing the same task. The remarkable finding is that Brain.fm's neural effects are much clearer in the participants who performed consistently on the visual task.

Since the task and music are unrelated, this phenomenon is hard to explain unless we suppose that the individual's neural response to the music somehow drives task performance (reaction-time consistency). Alternatively, some third factor could underlie both task performance and the neural response to Brain.fm, but it is hard to imagine what this might be. One possibility is that people who entrain better to tasks in general tend to benefit from Brain.fm music, which, after all, is designed to entrain brain rhythms. In other words, individuals differ in how entrainable they are, and Brain.fm appears to be more effective for people whose brains are better at entrainment.

What's next?

Research under our government grant is only beginning, but these initial studies are already delivering exciting results. We are now using other imaging methods (fMRI) to look at how music interacts with attention and memory, and plan a wide variety of tasks to look at how music affects behavior on a large scale.

A priority now is understanding the large and important differences we observe between people. What differentiates the groups of participants described above? Learning about who benefits most and why will allow us to further improve the music.

This document highlights one recent finding from our NSF-funded research on Brain.fm 'focus'. Additional results have been presented at conferences (e.g., Auditory Cortex, 2017), and are attached as supplementary material.