NeuroPop

We Can Change Your Mind...

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White Paper: NeuroPop – Sound Design, Technology Applications, Multimedia Consultation

Company Overview:

NeuroPop uses sound to map a world into the listener's brain. Our knowledge and use of sensory perception and neural processing allows us to modify any experience which uses sound to maximize its impact on an audience. NeuroPop's technology is based on cutting edge psychophysical and neuroscience techniques developed by major research centers, hospitals, universities, military, and intelligence organizations.

Services:

- **Adjust your audience's perceptual, attentional or emotional state by employing Neurosensory Algorithms (NSAs). NSAs use specially designed sounds to excite parts of the brain involved in processing sensory localization, emotional reaction and memory formation.**

  Audience/consumer recognition, recall, and response to a product name, logo or sound track requires very complex processing by the human brain. Brain regions which respond best to colors, movement, complex shapes, pitch, musical intonation, memory and emotional content are widely distributed throughout the brain, and all must work together to assemble these pieces into even the simplest perception. Military, NASA and university research into how the visual, auditory and balance senses are integrated have provided a wealth of information about how such information is coded in different parts of the brain. Human neurological research using cutting edge technology such as Positron Emission Tomography (PET) and functional Magnetic Resonance Imaging (fMRI) have helped map what parts of the human brain are involved in processing of complex emotions, sensations and memory. Using proprietary hardware and software technology, NeuroPop has developed a series of Neurosensory Algorithms which extract correlated features of these two areas of research to allow us to bias the brain towards desired mental states. These can include increasing or decreasing memory retention, fear, arousal, relaxation, and directing both auditory and visual attention.

  How well do NSAs work? Our current set of NSAs has been tested on several groups of subjects with startling success. Our first endeavor was to integrate NSAs into an audiovisual show performed live at several clubs in New York City. The show included spatial manipulators, emotional shifters and sexual arousal generators. Audience reaction was stunning and repeatable, with audience members reporting reactions of fear, relaxation, sexual arousal and physical affects such as vertigo. New Overload shows are planned for next spring in newer, larger venues. A remix of a Thrash-Metal song, "Rape Team" by Legend artist Bent, in which we deployed several arousal-increasing and sympathetic nervous system ("fight or flight") stimulating NSAs caused several of the recording team to flee the room, complaining of overwhelming fear and nausea – the reactions desired by the artist. Specific physiological and psychological effects of a limited subset of NSAs are currently being analyzed in a research project in the Psychology Department at Brown University.

- **Integrate sound into advanced technologies applications such as game-interface immersion, acoustic guidance and navigation, and communications/internet devices.**

  NeuroPop's scientific staff has been involved in projects funded by NASA, NIH, NSF, Office of Naval Research and the Deafness Research Foundation, in field ranging from applications of sound localization and navigation, to robotics, biological/cybernetic interfaces, remote nerve stimulation and recording and neural regeneration. While most of such information is proprietary, we can apply our theoretical and applied expertise in these projects to consumer and industrial applications. Such applications could include:

  - Wearable computer devices and avatar development
  - Optimized consumer electronics interfaces
  - Immersive virtual reality components.

- **Organization of visual and auditory information in such a way as to optimize or manipulate the audience's retention of that information.**

  Even relatively simple features such as the order of presentation of images and sounds, the pitch of a voice or timing between scene changes can have profound psychological effects on the audience or consumer. Psychological research over the last 50 years has demonstrated that the human brain has specific preferences in regard to which elements of sound and vision are processed in what order. At NeuroPop, our Research & Development group includes personnel with advanced degrees in psychology, biology and neuroscience who have worked on information analysis and optimization projects with universities, hospitals, the military and businesses. We can bring this expertise to bear on your projects.

- **Provide direct multimedia services, including full or partial custom composition and post-production audio mixing and recording.**

  NeuroPop's sound design studio in Manhattan's Upper West Side provides the perfect venue for clients in search of extraordinary productions. NeuroPop's recording and mixing capabilities are all digital and world class. We have an entire battery of state of the art software and hardware that we can bring to bear on any production.

  NeuroPop can immediately contact many of New York's top session musicians, arrangers, and composers to take your productions in any direction you may desire.

  Unlike anywhere else in the world, during post-production, you can ask NeuroPop's scientists and composers to take your project completely over the top with our proprietary NSA technologies.

Neurosensory Algorithms (NSAs): The Science of NeuroPop

Neurosensory Algorithms (patent pending) are NeuroPop's unique technology. NSAs are digitally designed acoustic signals that can stimulate discrete or limited regions of the human brain in such a manner as to bias a listener's attention, memory, emotional, or physiological state. NSAs are derived from best frequency and best temporal neural response characteristics of sound-sensitive and auditory processing regions of the brain. These regions have been partially mapped by comparative and human electrophysiological studies, electroencephalography (EEG), and neural imaging studies such as Positron Emission Tomography (PET) and functional Magnetic Resonance Imaging (fMRI) in awake, behaving human subjects. PET and fMRI have also identified relatively discrete regions of the brain involved in generation or expression of complex cognitive states involving specific emotional or attentional states. The unique feature of NSAs is their derivations from overlap of neurophysiological responses patterns from auditory electrophysiology studies and targeted response brain regions derived from neural imaging studies. By using NSAs to generate sounds that include best stimulatory components for auditory-sensitive neurons in these regions, it is possible to bias or modulate the listeners' attentional and emotional states.

Specific modalities

NSAs can modulate or drive three basic behavioral responses:

1) **sensory localization and orienting motor function**
2) **directing attention and changing memory load**
3) **inducing or modulating emotional and arousal states**

1. Sensory localization, orientation and attention:

Sound localization is a function carried out in the brainstem, particularly in the regions known as the superior olive (SO) and the inferior colliculi (IC). The perceived location of low frequency sounds in space is based on perceived temporal differences between components of the same sound between the two ears. These differences are known as interaural time differences (ITDs) and interaural phase differences (IPDs). ITDs, important for perception of transient sounds in the horizontal plane, and IPDs for complex, sustained sounds, are computed in the medial superior olive (MSO). The perceived location of high frequency sounds, while also subject to time of arrival differences, is phase independent, and horizontal localization of high frequency sounds is computed based on interaural intensity differences (IID and are computed in the lateral SO (LSO). Vertical plane localization of complex broadband sounds is dependent on spectral notches in high frequency regions (<5000 Hz) that are imposed by the passive filtering function of the pinna (outer ear).

Localization and movement of high and low frequency sounds in space are mapped in the IC. Connections within the IC integrate sensory maps from auditory, visual, and vestibular modalities. Based on the overlap of sensory maps, neural outputs from the IC connect with and help modulate orientation of the person towards points in space. Hence properly generated sounds are capable of modulating or driving eye, neck and body reflexes to orient the listener to the perceived source of the sound. For example, high intensity, low frequency sounds that are amplitude and phase modulated at very low rates can directly drive vestibular (balance/postural) responses by stimulating the sacculus, an organ normally unresponsive to sound. Complex modulated sounds whose apparent motion does not exceed a rate of 1 Hz can induce eye movements to specific regions from whence the sound appears to emanate. Projections to other regions, including oculomotor and vestibular processing regions in the brainstem can also contribute to sound-induced movements and changes of visual attention by the listener.

Localization and orienting NSAs use low- and high frequency carrier tones below the normal vocal range and above the normal musical range, respectively. The carriers are modulated at low frequencies, at rates appropriate to achieve response and neural synchronization by MSO, LSO and IC neurons. Mixed modulation rates of specific frequency bands achieve specific localization or orienting responses, including using best frequencies and amplitudes to achieve dislocated auditory/visual tracking which can result in vertigo, disorientation or nausea, and virtual sound location and virtual sound movement in three dimensional space for manipulation of attention (see below). In order to have these sounds work without use of headphones or specifically aligned speakers, the modulated carriers are embedded in low amplitude high bandwidth spatially correlated white or pink noise. The noise is filtered and constrained in such a way as to be barely perceptible to a normal listener; however, it acts to activate a wider range of hair cells in the inner ear than would normally be stimulated by modulated sine waves alone. This allows greater proportions of hair cells to synchronize in their response rate and yield the desired spatial perception effects without using high amplitude or highly directed sound fields (i.e., headphones).

Using combinations of carrier tones or noise with appropriate IIDs, ITDs and IPDs, the listener's visual attention can be guided to specific points on a monitor or screen, or in three dimensional space within certain constraints. By having the apparent location and phase of oculomotor driving sounds be out of phase with auditory sound position and movement, vertigo can be induced, whereas if left in phase, the perception of bodily movement can be induced.

2. Attention and Memory:

While visual and auditory tracking are important basic components of attentional processes, higher-level psychological processes are involved in selecting perceived objects for attention and transfer to long-term memory. The anatomical substrates for conversion of sensory data to long-term memory are only partly understood; however, certain brain regions are critical for this transformation. These regions include but are not limited to the hippocampus, the cerebellum and certain higher cortical regions. The basis of long-term memory formation lies in the inherent plasticity of the brain, and it's ability to undergo physical changes based on patterned input presented and repeated at appropriate rates. While memories are stored in a distributed fashion throughout the cortex, the structure known as the hippocampus may be critical for the transformation of short term or sensory memory into long-term memory. Elements of the hippocampus are known to undergo reorganization based on changes in correlated input. Neural responses above a certain temporal threshold can induce long-term potentiation (LTP), or an increased probability of enhanced neural events, whereas responses below this threshold are capable of inducing long-term depression (LTD), a decreased probability of responding to the same class of stimulus. Visual, auditory and vestibular systems all provide input to the hippocampus, which coordinates with cerebellar structures to form associations that can be stored in long-term memory.

NSAs which affect attention and memory are based on imposing differences in repeated stimuli to which habituation may occur, directly inhibiting or depressing response to certain stimuli, or associating stimuli with non-intrusive sounds with repetition rates which may enhance LTP and hence long term memory storage. These NSAs are generally composed of broadband white noise or carrier modulated noise sounds of short duration with stereo separation in the microsecond range; however, other carriers (tonal, harmonic waveforms) may be used in place of white noise. Stimulus presentation inducing low frequency neural response rates are associated with LTD, whereas those of higher frequency are correlated with LTP. The key to the utility of these NSAs is their placement within the other stimuli to be remembered, their repetition rate, and their placement in the virtual sound field relative to the visual elements with which they must be associated. To form appropriate associations with visual stimuli, such as video images, logos, etc, the NSA must be presented within a brief period (on the order of hundreds of milliseconds) before the presentation of the image, and it's spatial location and movement must be correlated with that of the visual image.

3. Arousal and Emotional State Induction

Arousal is a modulatory condition that prepares an individual for some action. It is driven through synergistic or opposing responses of components of the autonomic nervous system called the sympathetic and parasympathetic nervous systems and is often expressed through the limbic system of the cortex. Sympathetic stimulation yields the classical "fight or flight" reactions that involve behavioral responses to alarming environmental conditions. These can include pupillary constriction, increased pulse and respiration rates, suppression of appetite or induction of nausea, increased muscle tension, and complex emotional responses such as fear or aggression. Parasympathetic responses are evoked under non-threatening or relaxing conditions, and include pupillary dilation, decreased pulse and respiration, increased appetitive behaviors, decreased muscle tension and relaxation. Primary control of the autonomic nervous system is through the hypothalamus, which receives input through the limbic system and the reticular gray of the medulla, which is a major sensorimotor integration region. PET and fMRI studies have indicated that there are specific regions of the limbic system and other cortical regions which are associated with specific emotional reactions, e.g., the amygdala is implicated in fear, the orbitofrontal limbic association cortex is associated with anxiety and social perception, and the claustrum has been implicated in male sexual arousal. All of these regions receive extensive input from auditory nuclei in the brain, and hence are potentially targetable through NSAs.

NSAs that target arousal and emotional response are based on the sensitivity of the cortex to complex sounds and are loosely categorized into positive and negative arousers, primarily activating inputs to the sympathetic or parasympathetic systems. Sympathetic "fight or flight" NSAs use multiple high frequency carriers modulated with random phase or in such a way as to induce pseudo-random "beating" between carriers. This frequency range, in combination with random phase shifting creates effects similar to the "fingernails on the blackboard" effect. In addition, there are differences in arousal response to stimuli placed in the upper versus lower "visual" hemifields – stimuli perceived as coming from above the listener are often perceived as being more threatening than those coming from the lower field. Thus to increase arousal, the NSAs are notch filtered in such a way as to place their virtual position in the upper visual field . If these sounds are used in combination with low frequency spatial localizers with a different virtual movement in the horizontal plane, the resultant vertigo can combine with the sympathetic response to create highly distressing emotional and concomitant physiological responses in the listener.

NSAs which induce relaxation are synthesized using low to mid-frequency carriers with highly correlated phase modulation and spatial movement on the order of 1 Hz or less. Sounds including modified vocal formants and "pink" noise (1/frequency noise spectrum) are played at low repetition rates with durations on the order of 2-3 seconds with localization in the lower part of the sound field. These NSAs are typically pitch shifted upward by a specific proportion of their fundamental frequency within a brief time period. The upward sweep is correlated with partial left/right movement, corresponding to the percentage of the sweep. These are also combined with spatial localizing and attention directing NSAs but are restricted to movement in the horizontal plane at very low frequencies. By sweeping low and midrange modulated sounds left to right at very low frequencies, altered states of consciousness including trance-like states, relaxation, and suggestible conditions, can be induced.

Platform independent sound design for remixing into existing sound tracks

NSAs are constructed using combinations of sample playback, wavetable synthesis, subtractive synthesis, and appropriately placed modulators. Once constructed, NSAs are integrated into existing presentations or, in certain cases, presentations are constructed around, or from, NSAs. Integration procedure consists of analyzing final presentational requirements, such as overall structure of surrounding material (tonalities, stylings, instrumentation, tempi, duration, etc.), audience demographics, and desired psychophysical effects. Once elements are determined, appropriate NSAs are selected and tuned, and material is composed, arranged, or re-arranged accordingly.

Upon completion of musical or audio arrangement, individual elements are mixed for final recording to formats appropriate to final presentation. An additional multiband mastering process, though not required, is often employed to intensify the NSAs without altering perceived quality of a presentation.

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