Exeo Entertainment, Inc.
Presents

Psyko Audio Labs, Inc.
Surround Sound Technologies for Headphones

Introducing Psykowave™

Contents

SUMMARY

If you close your eyes and someone walks into the room and speaks you instantly know the location of the person. How is it possible to detect direction in 360 degrees with only two ears, and can headphones provide the same audio experience?

Our ability to place the location of a sound source is a result of three factors: the different distance sound has to travel to each ear, the different intensity with which sound hits each ear, and the effect of sound reflecting inside the external part of the ear – the pinna – before entering the ear canal. Our brain combines these inputs to tell us where the sound is originating.

Until now, headphones have tried to simulate 3D sound using software (HRTF methods) or multiple speakers in each ear cup. But neither method correctly reproduces the directional cues to everyone. Our ears are as unique as fingerprints, so these have never resulted in true surround sound. If there is any front-to-back effect many people say it does not sound natural.

Psyko Audio's patented technology uses a completely different approach. By generating the sound away from the ear and sending it to both ears along precisely engineered audio channels, Psyko headphones utilize the each person's pinna as part of the sound experience and the precise timing differences. The result is precision directional audio.

Gamers using Psyko headsets report a fuller, more realistic and more natural surround experience, giving them a distinct competitive edge and richer immersion.

1 INTRODUCTION

Psyko Audio Labs Inc. has developed a novel and patented solution to producing surround sound audio in headphones. Psyko™ technology creates a radically more natural audio feel than what has been accomplished by previous methods.

The human brain forms a rich sound image of its surroundings by using the sound signals from just two locations - the ears. Just as everyone's fingerprints are unique, so are their ears. Psykowave is the only technology that instantly creates the precise 3D sound cues uniquely for each person. Users describe the result as the most natural 3D sound ever.

This White Paper describes:

1. How humans detect the location of sounds,
2. The two old headset methods that attempt to produce 3D audio, and why they cannot fully reproduce 3D images.
3. How the new Psyko audio headset works to accomplish deliver precision directionality.
4. The benefits of correctly hearing 3D sounds.

2 HOW WE LOCATE SOUNDS

Imagine you are sitting outside and you close your eyes. You hear a footstep and you instantly know that it is in front of you and to your right. How did you know? The answer is two ears and an amazing wiring in your brain. The study of how sound is perceived is called psychoacoustics. That's where Psyko got its name.

Sound travels as a wave and bounces off everything it hits. When the sound wave from that footstep traveled past your head it was heard by one ear before the other ear. As it flowed past your head it also reflected off your ears to create a unique sound signature at your ear drums. In that instant your brain decoded three pieces of information from the wave and formed a map of where it came from, as follows:

The cues humans use for locating sounds[1] are:

1. Timing differences between each ear,
2. Intensity (sound level) differences between each ear,
3. Frequency modifications (the pinna effect).

2.1 Timing

For a sound coming from the front right, as shown in Figure 2.1, the sound hits the right ear slightly before the left ear. The timing difference is one cue to how far to the right the sound is located. This is also known as the Inter-aural Timing Difference (ITD). This can vary from 0 to approximately 0.7 millisecond.

That's a very short time. Human brains have specialized wiring to detect extremely tiny changes in this timing. People can detect the angle of a sound within 5 degrees. That is a change of 0.04 milliseconds (0.00004 seconds)!

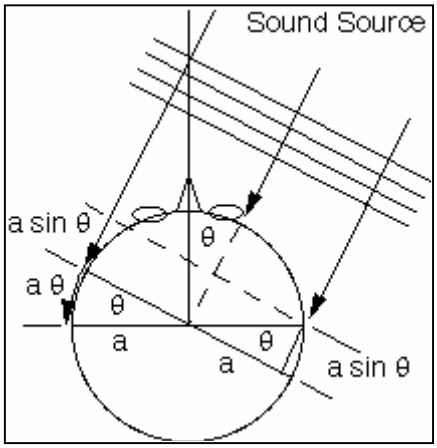


Figure 2.1: Sound Source 30 Degrees Right of Front

2.2 Intensity

Again, in Figure 2.1, the sound wave reaching the left ear is blocked somewhat by the head and therefore the sounds are louder to the right ear than to the left ear. This is known as the Inter-aural Intensity Difference (IID).

[1] Figures and text for this section used with permission from http://interface.cipic.ucdavis.edu/CIL_tutorial/3D_home.htmh
"These notes provide background on 3-D sound. They were originally prepared for an NSF-sponsored course entitled Human Computer Interface Design. Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted with or without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and full citation on the first page. To copy otherwise, to republish, to post on services, or to redistribute to lists, requires specific permission and/or a fee."

2.3 Frequency Modification (Pinna Effect)

With the above two cues there is still the problem that sound coming from the front right has the same timing difference (ITD) and similar intensity difference (IID) as if the sound was coming from the rear at the same angle. This is where the ear shape (the pinna) comes into play.

When sounds travel past the ear, some of the wave enters the ear canal directly while some of the sound travels past the ear canal and reflects off portions of the outer ear before also entering the ear canal. This slight change in distance travelled by the reflected wave means that some sound frequencies entering the ear canal are amplified while some frequencies are cancelled by the reflected waves. The ear has a complex shape, so the distance travelled by the reflected waves, and the amount of amplification and cancellation, depends on the angle at which the sound is coming.

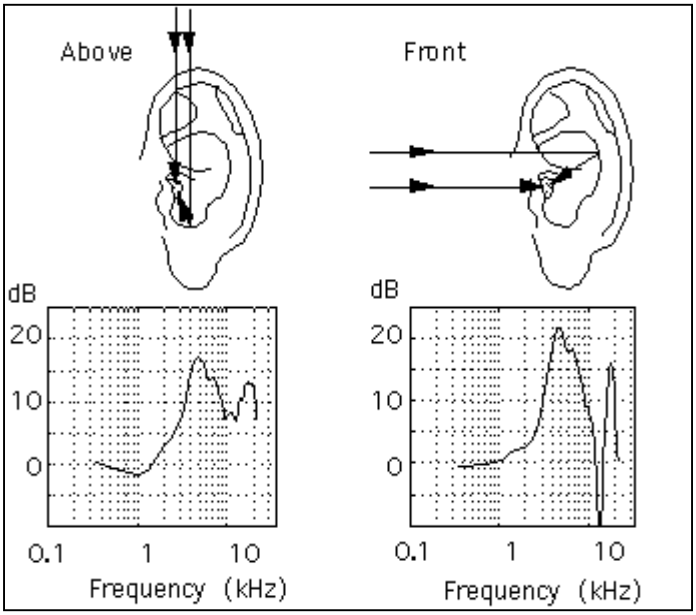
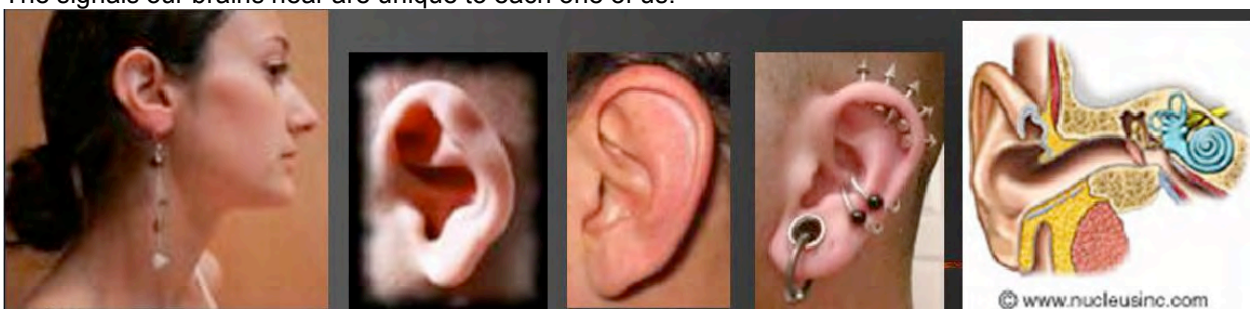


Figure 2.2: Sound Signatures for Sound From Above and From Front

Every angle around the ear, in every plane, produces a unique sound signature. Sounds from the front sound different from the same sound coming from above (see Figure 2.2) or from the rear or from any angle around us. Our brains are used to hearing sounds from each angle having all those sound signatures. Since everyone's ears are as unique in shape as fingerprints, the sound signatures are unique to each person. In fact, even the right ear is unique from the left ear. The signals our brains hear are unique to each one of us.



Everyone's brain automatically, and totally without us being conscious of it, constantly interprets these unique sets of signals to create an image of the 3D sound world.

Only when all these separate cues work together do we have the impression that the sound from a headset sounds natural. The next sections will describe techniques that try to emulate these cues, and how Psyko technology best reproduces the sound field that is unique to each of us.

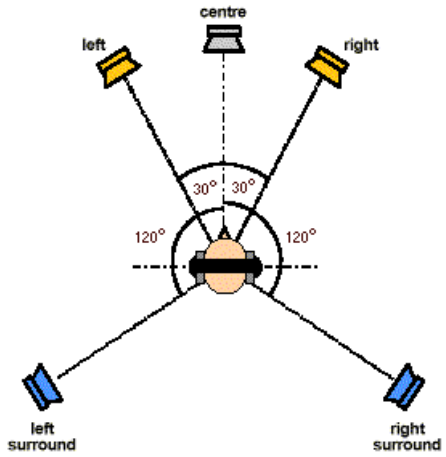
(There are some people that can't localize sounds. Hearing loss in one ear or hearing loss of certain frequency ranges will reduce the ability to localize sounds.)

3 PREVIOUS METHODS FOR HEADSET SOUND LOCALIZATION

Over the last 20 years, various methods have been developed to try to produce sounds in a headset that create sound localization. These methods can be generally grouped as

1) Virtual (or simulated) Methods and
2) Multi-speaker ear cup Methods.

These methods attempt to reproduce the effects of a surround sound room speaker system. A typical 5.1 layout is shown here.

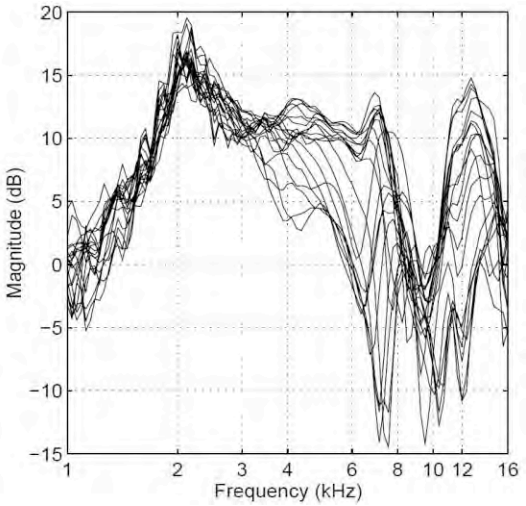


Speaker angles for 5.1 audio.

3.1 Virtual Methods

This method involves altering the sound to be played to give the impression of surround sound in a traditional 2-speaker headset. This method is typically called virtual or simulated surround sound. The version made by Dolby is called Dolby Headphone, whereas some companies have their own method to simulate surround for a traditional headphone. If they are made for a 2-speaker headphone they fall into this category.

When the game plays a sound at a given location a digital signal processor, DSP, uses a mathematical algorithm (the simulation method), to alter the EQ in an effort to simulate a pinna effect, like one of the curves shown like in Figure 2.2 above, and may add the timing and frequency dependent intensity difference for each of the 2 speakers in the headset. It is complicated and takes time to process (adds latency). When the sound moves from one angle to another in the room the DSP has to try to smoothly transition the output from the curve defined at one angle to the curve defined at another angle. This transition often introduces unnatural sounding transitions, or jumps in how the sound is delivered.



These are curves for 19 angles around one person's head. This method must transform every sound by such curves. Every person requires a unique set of curves.

The algorithms to produce these sound modifications are called Head-Related-Transfer-Functions (HRTF). One of the several challenges in the HRTF method is that it produces one package of signatures – one audio signature for each simulated speaker. However, everyone's ear shape is unique and creates its own audio direction signature; so, the result is that this method only works for some people. It depends on whether your ear shape matches that of the algorithm they use. This method is like hearing the sounds through someone else's ears and does not

sound natural to most people. Research shows the use of someone else's sound signatures dramatically increases errors in sound localization[1]. Some claim that any given algorithm only works for 20% of people.

Some people report that after using the headsets for a while they begin to get the 3D effect better. This is the result of the brain learning how to process the given sound cues, but it still is not described as sounding natural.

This method requires extra processing of the sound which can be performed on the computer, which slows it down, or done on a dedicated computer chip that comes with the surround sound headset to perform it. Given the low price of headsets compared to a computer, the chips they use are usually very inexpensive and not very powerful so there is a loss of fidelity of the signal and they introduce latency, which is a delay in delivering the audio. A small delay between the visual cue and audio cue can be irritating; a large delay can be distracting. Latency in gaming means others hear the action before you do, which means you are at a disadvantage.

Using the same virtual, or simulated surround sound algorithm for everyone, is like using the same prescription for eyeglasses to everyone in the world. We all need our own prescription in glasses, and in headphones.

Problems with virtual surround sound.

1) Does not work for most people.
2) Introduces latency
3) Transitions from one virtual speaker to another can sound unnatural
4) Distorts the sound (loss of fidelity)

[1] Wenzel, E. M., Arruda, M., Kistler, D. J. & Wightman, F. L. Localization using nonindividualized head-related transfer functions. *J. Acoust. Soc. Am.* **94**, 111–123 (1993).

3.2 Multi-speaker Ear Cup Method

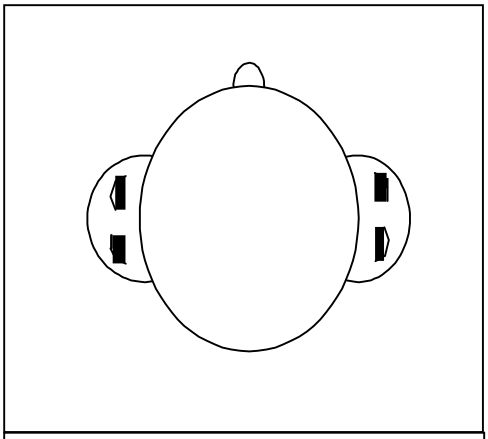


Figure 3.1: Multiple speakers placed around each ear.

Various designs have been produced in which multiple speakers in a headset are placed around each ear. For example, the 5.1 signals that normally go to the left front room speaker are sent to a speaker that is placed slightly in front of the left ear, and the left rear signal is sent to a speaker slightly behind the left ear. In fact, because they jam so many speakers into the ear cup the location of the speakers may just be where there is room and they may use small speakers.

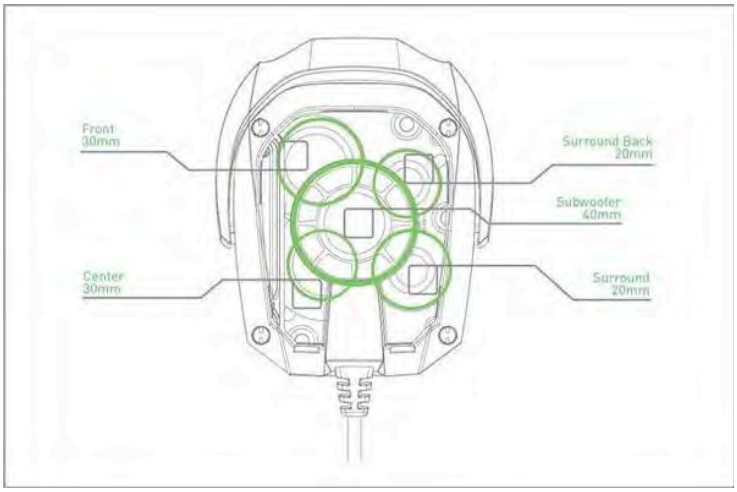
In some of these cases there are circuits to modify the polarity or emulate the time delay between speakers, in some cases there is little that these headsets do to produce the sound cues described above. They typically don't correctly produce a timing difference (ITD) between left and right ears, or an intensity difference (IID. So a sound that would be sent to, say, the front left room speaker, is taken by these headphones and heard by only the left ear, not by both with the correct timing as is natural.

In the cases used in the commonly available headsets, these speakers are clustered beside each ear, so there is little angle difference between them and little or no production of the Pinna Effect. They may use different sized speakers for each location to make the sound different for each location. Not the pinna effect, just each speaker sounds different.

Problems with the Multi-Speaker Ear Cup Method

1) poor or no pinna effect
2) Poor or no timing difference between ears,
3) Poor or no intensity difference between ears

Now there is a better way to provide a natural 3D audio experience than virtual or multi-speaker ear cup methods.



For more details comparing various headphone systems see "Technologies for Presentation of Surround-Sound in Headphones" (HeadWize Design Series Paper) http://www.headwize.com/tech/sshd_tech.htm and for details on left/right ear cross-over for headphones see http://www.headwize.com/tech/headrm1_tech.htm

4 *PSYKOWAVE™ TECHNOLOGY*

Psykowave™ patented technology is a major advance in headset technology. It features:

Wave guides to carry the sound from each speaker to both ears.

A precise location in the wave-guide for each speaker to represent a specific location of each speaker in a room.

A controlled method to guide the sound to the correct angle to each ear for the Pinna Effect.

The sounds for the front speakers are guided to the front of the ears to create their correct Pinna Effect. Likewise, the sounds for the rear are guided to the rear of the ears for their correct Pinna Effect. The timing difference (ITD) is accomplished by spacing the left and right speakers at appropriate locations. For example, a room speaker in front of you and at a 30 degree angle will create sound that reaches your right ear about 0.35ms before it hits the left ear. To reproduce the 30 degree angle, Psyko places this speaker at a precise distance right of the centreline of the headset so the right ear will also hear its sound 0.35ms before the left ear does.

The wave-guides contain acoustic features that produce the intensity drops (IID) as created by the sound traveling around the head.

Unlike the virtual methods, the Psykowave technology has no latency, a pinna effect unique to each person and the transition from one position to another requires no interpolation functions. In fact the Psykowave technology is exactly like a room speaker system, where the sound moves completely smoothly from one position to another.

Unlike the headphone systems that put multiple speakers in each ear, the Psykowave technology delivers precise timing and volume difference between the ears and an accurate pinna effect.

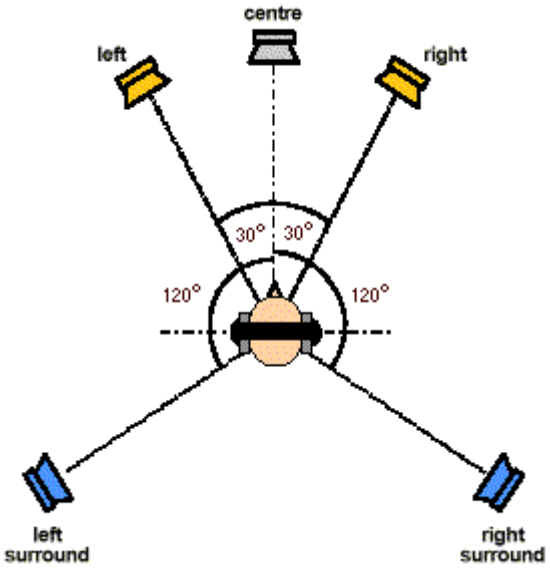
This is the only method that instantly delivers all three sound cues:

1) Timing - ITD,
2) Intensity - IID and
3) Pinna Effect for every person.

All with zero latency because there is no digital signal processing.

This technology is adaptable to any number of speakers in the room, from 2.1 to 10.2 and beyond. Even sounds coming from above the head can be produced accurately by this technology.

The headset produces the same directional effects as those from room speakers. Users of the Psyko headset describe the effects as sounds as being directionally precise.



Speaker angles for 5.1 audio.

5 ADVANTAGES OF 3D SOUND AS ILLUSTRATED BY RESEARCH FINDINGS

Psycho-acoustic research[2] has shown several areas where 3D sound is beneficial:

5.1 Binaural Gain

Binaural sound is when both ears hear the sound with the correct timing.

Probably the single most important fact about binaural audio is that if an audio signal is played on top of white noise it will appear six to eight decibels louder if that signal is a binaural signal versus a non-binaural signal. This means that the exact same audio content is more audible and intelligible in the binaural case, because the brain can localize and therefore "single out" the binaural signal, while the non-binaural signal gets washed into the noise.

5.2 The "cocktail party effect"

At a cocktail party, a listener is capable of focusing on a conversation while there are dozens of other conversations going on all around. If that party were recorded and then played back using a regular mono or stereo procedure, all the conversations would be combined into one (mono) or two (stereo) locations. The result would in most cases be unintelligible. With 3D audio recreation of that party, a listener would still be able to tune into and understand individual conversations, because they are still spatially separated and "amplified by" binaural gain.

[Third party research showed Psyko headphones to have superior multi-channel voice intelligibility and are the first headphones to be certified by a national regulatory body for use in black box playback in the civil aviation industry.]

5.3 Faster reaction time

In an environment such as an aircraft cockpit, where a lot of critical information is displayed to a user, reaction time is crucial. Research documents that audio information can be processed and reacted to more quickly if presented in 3D because such a signal mirrors the ones received in the real world. In addition, these signals can convey positional information: a 3D audio radar warning sound can warn a user about a specific object that is approaching (with a sound that is unique to that object), and naturally indicate where that object is coming from.

5.4 Less listening fatigue

Phone operators who listen to a mono headphone signal all day long experience listening fatigue. If those same signals are presented as binaural signals, listening fatigue can be reduced substantially. Humans are used to hearing sounds that originate outside of their heads, as is the case with 3D signals. Mono and traditional stereo headphone signals appear to come from inside a listener's head when using headphones (a.k.a., in-the-head-fatigue), and produce more strain than a natural sounding, 3D signal.

[2] Original source is http://www.headwize.com/tech/aureal1_tech.htm#intro

5.5 Increased perception and immersion

Some of the most interesting research into 3D audio shows that a subject will consistently report a more immersive and higher quality ("nicer" colors, or "better" graphics) environment when visuals are shown in synch with 3D sound, versus stereo sound or no sound at all.

“The findings of a large number of research studies indicate that interactive 3D audio is an important technology that enables an entirely new level of audio experience: a three-dimensional sound field is created in real time to continuously envelop a listener. The listener is no longer aware of the audio system that is rendering the sounds - the application communicates directly with the user, creating levels of awareness, realism, immersion, and increases in reaction time and communication of audio information previously only possible in real-life situations.”

6 PSYKO AUDIO LABS GAME RESEARCH

Video gamers using Psyko gaming headsets report that they feel a measurable improvement in their game performance and they become more immersed into the game. They attribute this to being able to hear precisely the location of every sound. They also report that when they go back to their own headsets that the sound is muffled or dead. They report that the sound from the Psyko headset is more alive and dynamic. The directionality is precise.

7 CONCLUSIONS

PsykoWave™ technology creates the truest 3D sound experience.

- Unlike the multi-speaker ear cup method, it accurately produces the sound cues you need (ITD, IID, Pinna effect), in the customized way that **only you** are used to hearing.
- Unlike the HRTF -- or virtual -- methods, you are not hearing them through someone else's ears, so the sound is as natural as possible. Using the same HRTF method for everyone is like using the same prescription for eyeglasses to everyone in the world – but we all have unique needs for glasses, and unique needs for 3D audio.

	All Three Cues Needed For Full Directional Effect (3D Audio)			Other features
Headphone Technology	Inter-ear Timing Difference	Inter-ear Volume Difference	Pinna effect	Transition between positions
PsykoWave™ Technology	**Yes**	**Yes**	**Yes**	**Smooth**
Simulated Surround (HRTF, DSP methods), in stereo headphones	Should be	Should be	Someone else's ears	Interpolation, can by jumpy
Multi-speakers in each ear cup	Not a part of this technology	Not a part of this technology	Poor	Smooth
Stereo headphones	No	No	No	Smooth

The benefits of accurate 3D sounds and **Psyko** technology are many:

Improved reaction time. You win more.
Improved game immersion. It feels more real.
The sound experience is more audible and intelligible so you can actually turn down the volume compared to other headsets; this reduces the danger to over-exposing your ears and creating hearing damage.
Improved "cocktail party" effect. You can selectively listen to each event occurring around you even in a busy audio environment.

Reduced In-The-Head Fatigue. You can play without getting tired of the decoding an unnatural sound.
Even the visual experience is enhanced when the sound is 3D.
Zero latency.

You accurately hear where the action is around you. This helps you compete in your game better and gives you a fuller experience of the game. In watching movies it enhances your immersive experience.

In side-by-side tests with other headsets, users say the Psyko headset sound is more alive, directionally precise and natural than any others.

For information about purchasing go to:
www.exeoent.com

Or contact:

Exeo Entertainment, Inc.
4478 Wagon Trail Ave
Las Vegas, NV 89118
702-361-3188