5D Audio in VR

Expanding 3D audio to enhance VR experiences using higher dimensions of sound

PREPARE TO EXPAND YOUR MIND

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Outline

Part 1: Expanding your Dimensional Awareness

Part 2: How we hear and process sound

Part 3: 5D Audio

About Me

Sound Designer and Composer

Austinite

11 years in games

EA, LucasArts, Raven, Naughty Dog, GL33k, Epic, Starbreeze StarVR

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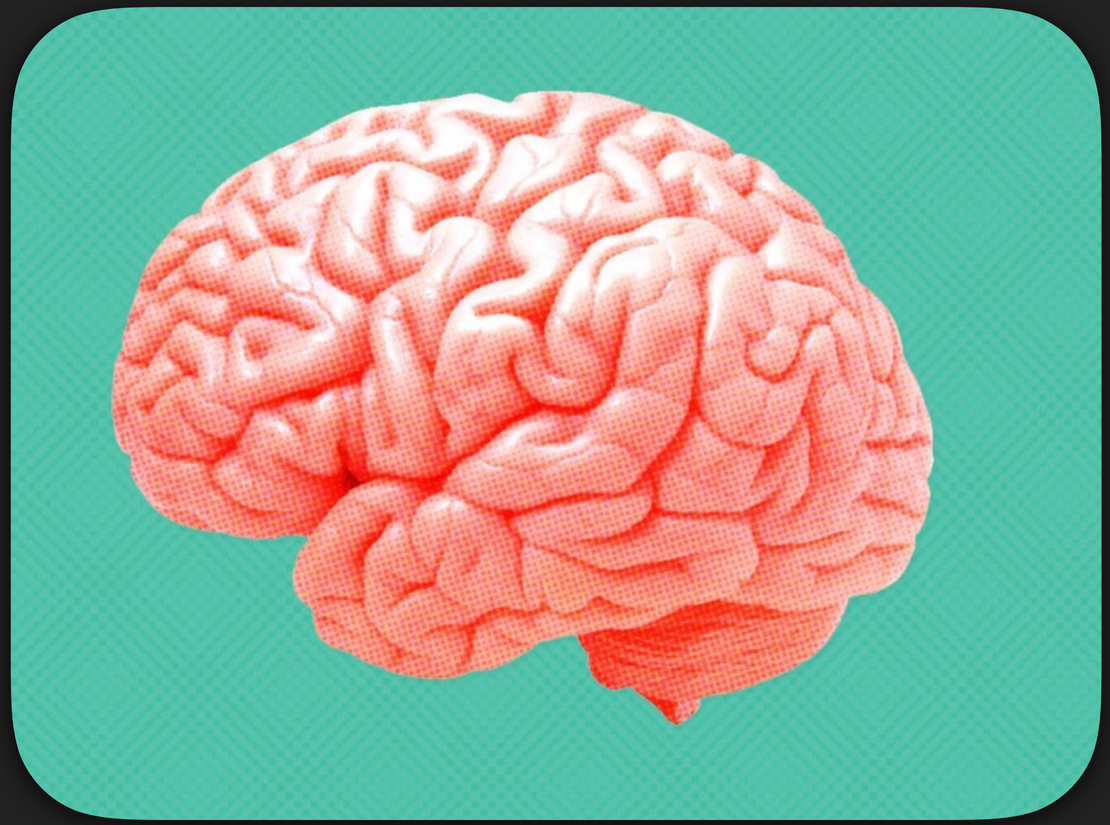
So what?

What do I know about hacking the brain?



Part 1

Expanding your Dimensional Awareness

What is 5D Audio?

What is 5D Audio?

A BuzzFeed, clickbait headline?

What is 5D Audio?

A BuzzFeed, clickbait headline? It Worked!

5D Audio is what we experience every moment of our existence.

WE ACTUALLY EXIST IN A SLICE OF THE 5TH DIMENSION.

OUR CONCEPT OF “NOW" IS MERELY A MOMENTARY SNAPSHOT OF AWARENESS IN A 5D PROBABILITY SPACE IN A MOMENT OF 4D TIME AND LOCATED IN 3D SPACE.

Wait a minute Aaron, I thought you said this wasn’t going to get complex.

Geek
Speak
Alert!

The Dimensions

Definition of ‘Dimension’

Measurable extent or quantity that denotes the degree to, or range over, which something extends.

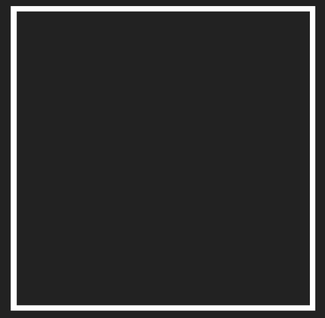
1D

Quantity = Length

The Dimensions

2D

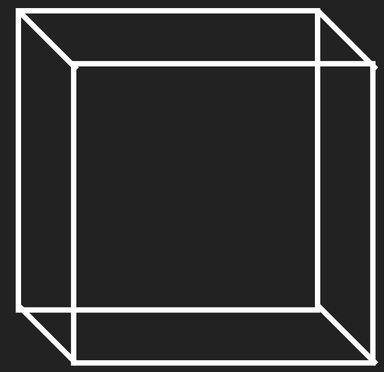
Quantity = Length, Width



The Dimensions

3D

Quantity = Length, Width, Height



The Dimensions

4D

Quantity = Length, Width, Height, Time

The Dimensions

5D

Quantity = Length, Width, Height, Time, Choice/Probability

This is the dimension we actually exist in every day based on our choices.

The Dimensions Summary

2D = slice of 3D space

3D = snapshot of 4D time

4D = slice of 5D out of all possible probability outcomes

5D = the slice we perceive every day

Part 2

How we hear

Geek
Speak
Alert!

Hearing System Overview

Objects vibrate and push volumes of air, that air pushes other volumes of air in all directions and collides with objects in the world, this eventually reaches our head and both of our ears which eventually hits our ear drums, it then goes through the three ossicles (hammer, anvil and stirrup) into the oval window which transmits sound through fluid around the basilar membrane within the cochlea, the fluid of sound then hits the round window at other end while fluid in the cochlea resonate certain sections of the basilar membrane based on frequency (high first then low), the tectorial membrane activates sensory hairs that get pushed and pulled by sounds, (1,500 inner hair cells talk to 20 neurons each to detect the sound frequencies while 3x that amount of outer hair cells share neurons between them and dance around while getting signal which amplifies that signal), as the hair cells bend potassium flows to activate electrical currents as they detect signals which go to neurotransmitter axons into the spiral ganglion to get decoded by multiple brain centers which then derives context such as location, pitch, and meaning from that initial air movement.

Hearing System Overview

It’s super complicated….

Would take much more than 60 minutes just for this topic.

How we process Sound

Our brains and ears are constantly monitoring and making sense of our world full of an overwhelming amount stimulus possibilities.

Our brains are pattern seeking machines

The Auditory System analyzes THOUSANDS of events per second

- Outer hair cells alone move 15,000 per second!
- There are about 20,000 hair cells in EACH EAR!

How we process Sound

If a tree falls in a forest, do our brains process it?

Sounds that occur in the world may not even make it to our basilar membrane, let alone our brain or focus!

Tools will come and go, but our brains perception of sound has been wired over hundreds of millions of years of evolution.

Part 3 - 5D Audio

5D Audio

Players Subconscious Mind

- Players exist in a 5D world of choices
- **Our brains are pattern seeking machines**
- Our subconscious auditory processes running all the time
- All the following processes are effecting the player experience 100% of the time.
  - The player’s are unaware of this
  - You are HACKING the player’s mind and choices using their ears!
  - NEAT

StarVR Headset Immersion Level

STARVR HEADSET SPECS

In complete visual immersion how can you guide the player where to focus?

HACKING THE PLAYER'S BRAIN WITH 5D AUDIO

- INFLUENCE CHOICE
- IMPROVE MIX CLARITY
- IMPROVE IMMERSION
- ORGANICALLY DRIVE GAMEPLAY
- TRIGGER EMOTIONS

INFLUENCING CHOICE USING
CONTRAST

Influence Choice - Contrast

5th dimension is one of choices

How do we influence choices?

Providing clear focus using sound

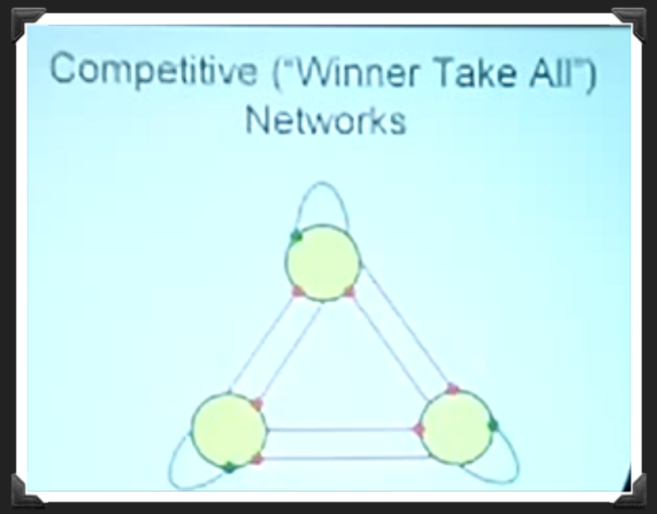
Influence Choice - Contrast

FACT: Our brains can only focus on one new thing at a time.

Loops in prefrontal cortex involved in action selection works this way to choose predominant action based on relevant importance.

These RETUNE YOUR SENSES from the PFC down to sensory systems.

WINNER TAKES ALL!



Influence Choice - Contrast

One Focus Point to win them all

This Focus Point controls our sensory systems and actions

How do we hack the player brain to control their focus?

CONTRAST **CONTRAST**

CONTRAST

Influence Choice - Contrast

“Attention is about picking important information from the sensory clutter that the world (and your brain) throws at you twenty-four hours a day. At the simplest level, it is just the ability to focus on some events while ignoring others.”

Universal sense

Influence Choice - Contrast

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Influence Choice - Contrast

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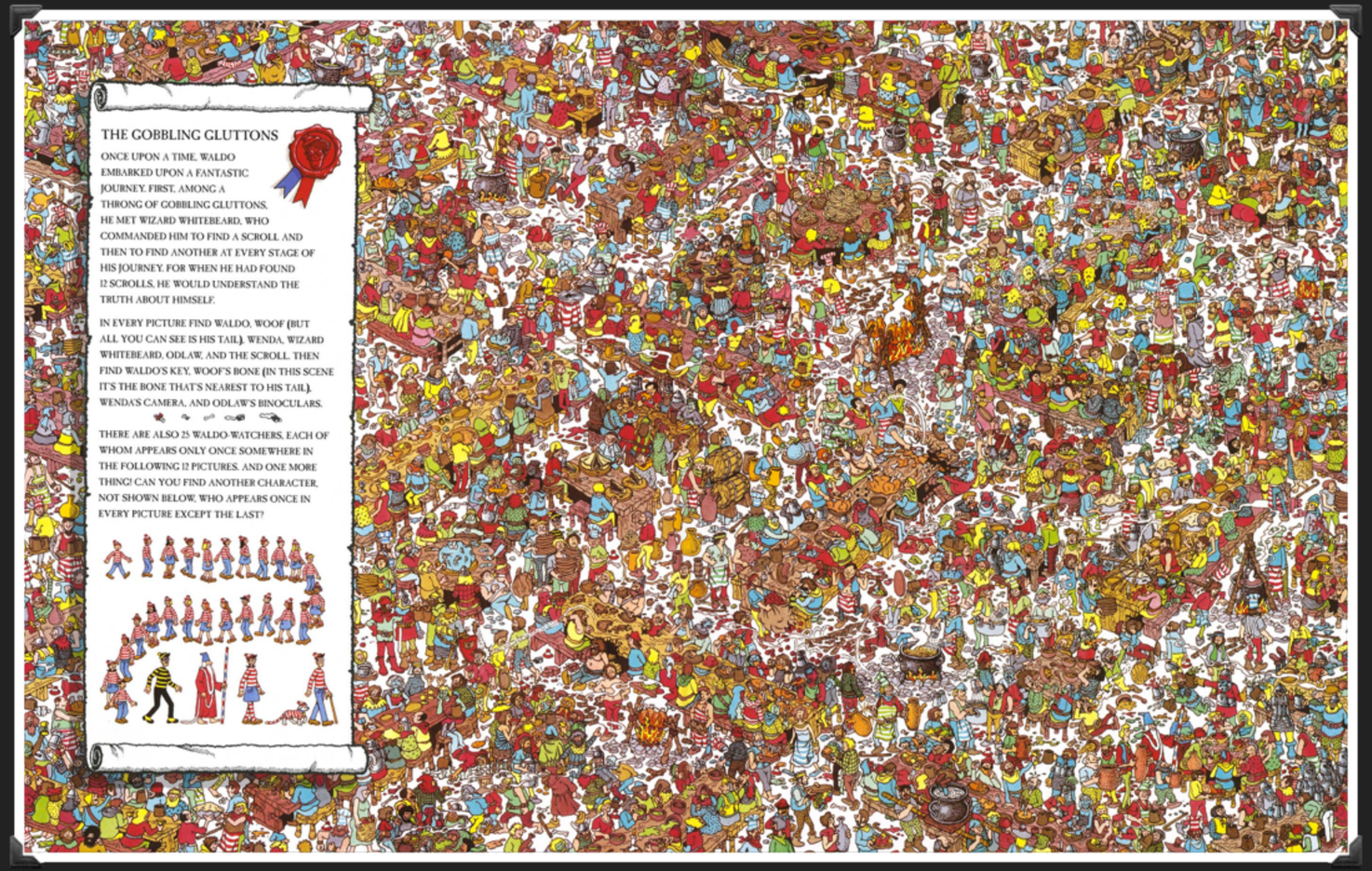
Basically, the whole concept behind Where's Waldo



Influence Choice - Contrast

Contrast is key in determining focus.

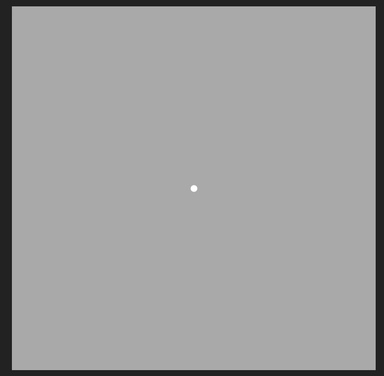
Brain Analysis Paralysis: You send more signals from your PFC to your auditory neurons than your auditory neurons send to your brain!

Heighten the senses: Higher dynamic range and contrast between levels and frequency content allows users to have a clear focus

Influence Choice - Contrast

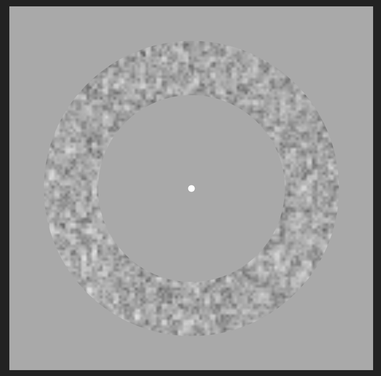
Pattern detection test:

Stimulus:



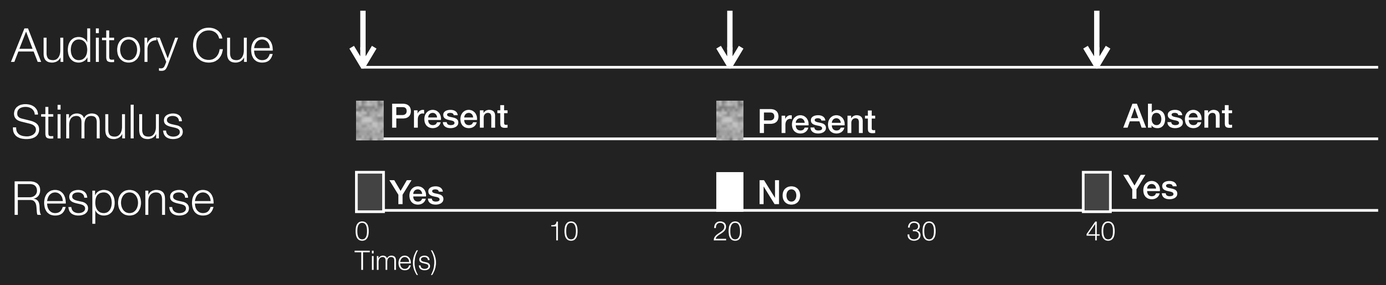
Uniform field

versus



Threshold contrast pattern

Stimulus:

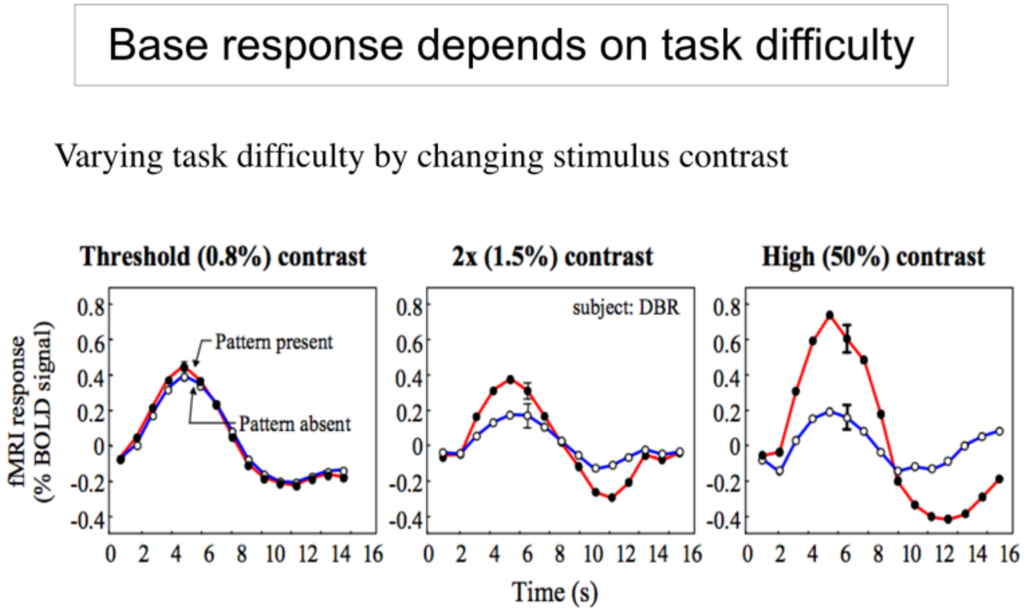


Influence Choice - Contrast

Pattern detection test results:

Base response depends on task difficulty

Varying task difficulty by changing stimulus contrast



Easier task:
- attentional response decreases
- sensory-evoked increment in response increases

Influence Choice - Contrast

Silence is Golden

Since we are always presented with subconsciously monitored background noise, a sudden lack of outside sound leaves an awful lot of attentional and arousal control bandwidth available.

The detection of the absence of sound, while slower than the detection of a sound, triggers its own set of responses, increasing attention and arousal, which can lead to internal mechanisms of increasing your ear’s gain or sensitivity.

Influence Choice - Use Of Silence In Star Wars

Influence Choice - Contrast

SUMMARY

CONTRAST CREATES ORGANICALLY DRIVEN FOCUS POINTS FOR THE PLAYER.

The bigger the contrast, the higher amount of attention an event will get.

INFLUENCING CHOICE USING FREQUENCY SELECTION

Influence Choice - Frequency

BRAIN ADAPTS TO IMPORTANT FREQUENCIES AND TELLS OUR AUDITORY SYSTEM TO GIVE THEM MORE ATTENTION

Our brains are pattern seeking machines

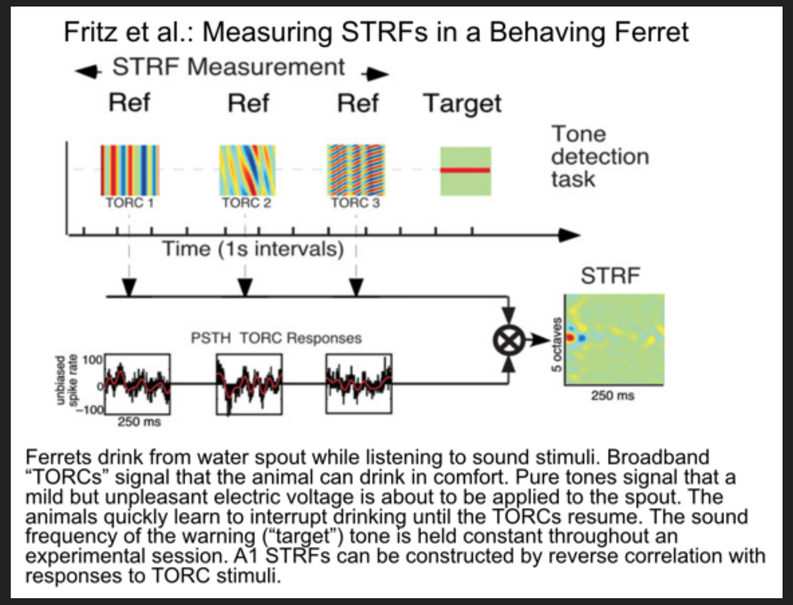
For the task engaging the player, the Prefrontal Cortex associates important information with frequency content, then tells the ears to be more sensitive to those frequencies.

Geek
Speak
Alert!

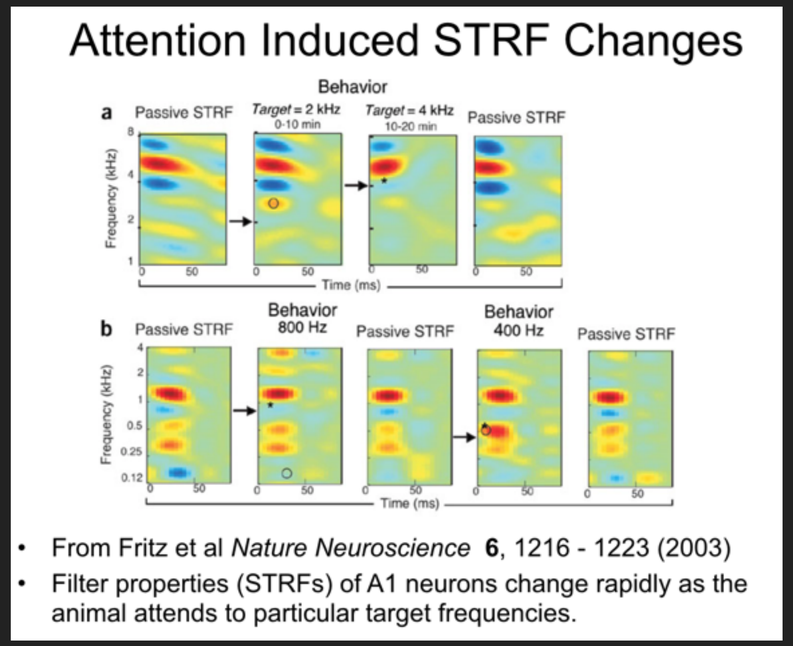
Influence Choice - Frequency

Focus through Critical Frequency Content

Study measuring how the brain alters focus to certain frequencies based on perceived importance to task at hand.



Ferrets drink from water spout while listening to sound stimuli. Broadband "TORCs" signal that the animal can drink in comfort. Pure tones signal that a mild but unpleasant electric voltage is about to be applied to the spout. The animals quickly learn to interrupt drinking until the TORCs resume. The sound frequency of the warning ("target") tone is held constant throughout an experimental session. A1 STRFs can be constructed by reverse correlation with responses to TORC stimuli.



- From Fritz et al *Nature Neuroscience* **6**, 1216 - 1223 (2003)
- Filter properties (STRFs) of A1 neurons change rapidly as the animal attends to particular target frequencies.

Influence Choice - Frequency

Habituation

“*Overpresentation of any stimulus often leads us to ignore it. Habituation is characterized by diminished responses to the same stimulus over multiple presentations.” - Universal Sense*

It also kicks in faster and lasts longer if the stimulus is repeated more rapidly with shorter intervals

However, the response can be restored if a different frequency is presented occasionally

Influence Choice - Frequency

HABITUATION IS THE OPPOSITE OF ATTENTION INDUCED STRF

FACT: The Brain can both INHIBIT or AMPLIFY our hair cell sensitivity to frequencies and sound based on time and perception.

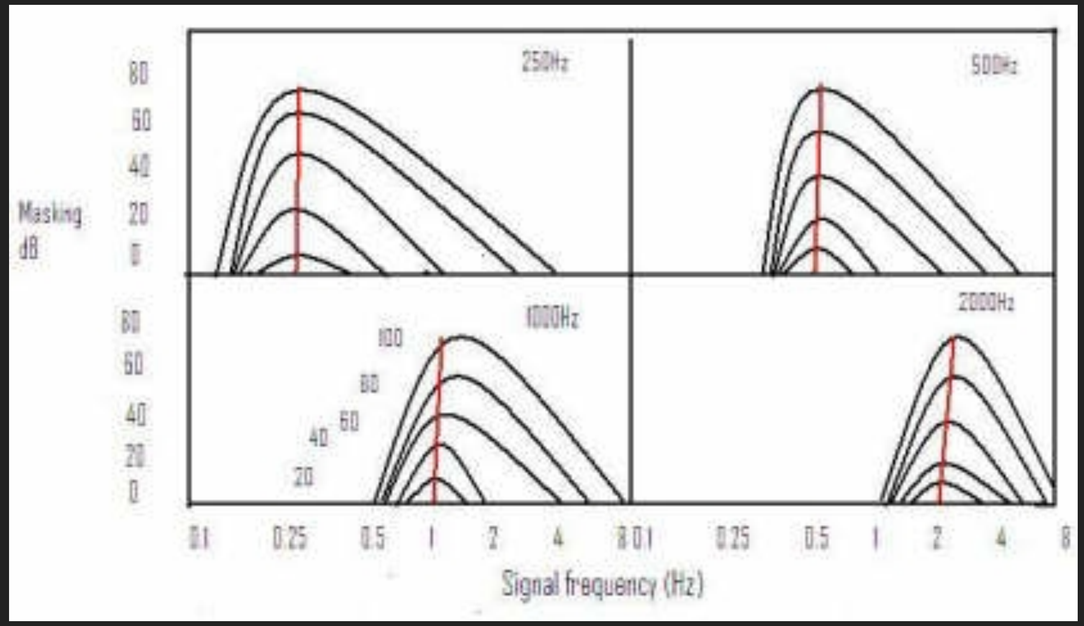
Influence Choice - Frequency

MASKING

Louder sounds cover up softer sounds.

FREQUENCY MASKING

Masking effect highest at same frequency, but also affects surrounding frequencies.

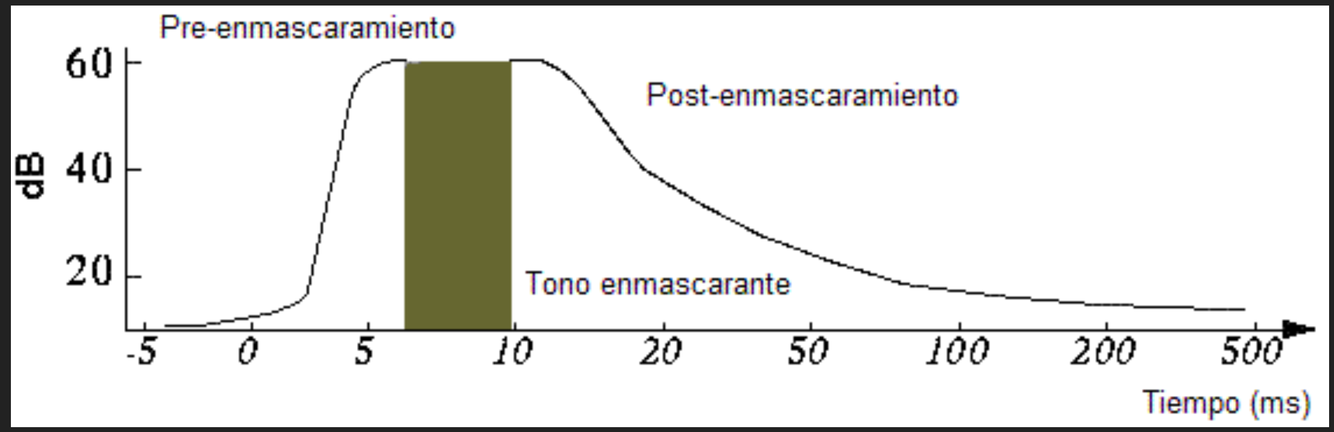


Influence Choice - Frequency

TEMPORAL MASKING

Temporal masking is a 4D time domain phenomena by which masking can be exploited before and after a signal.

There are up to 20ms of pre-masking before the signal occurs and 50-200ms of post-masking after the signal finishes.



Influence Choice - Frequency

SUMMARY

FREQUENCIES CREATE ORGANICALLY DRIVEN FOCUS POINTS FOR THE PLAYER.

The Brain tunes ears to important frequencies

The Brain decreases sensitivity to overused frequencies

The Brain dynamically tunes our auditory system

IMPROVE YOUR MIXES USING FREQUENCY SELECTION & CONTRAST

Improve Your Mixes

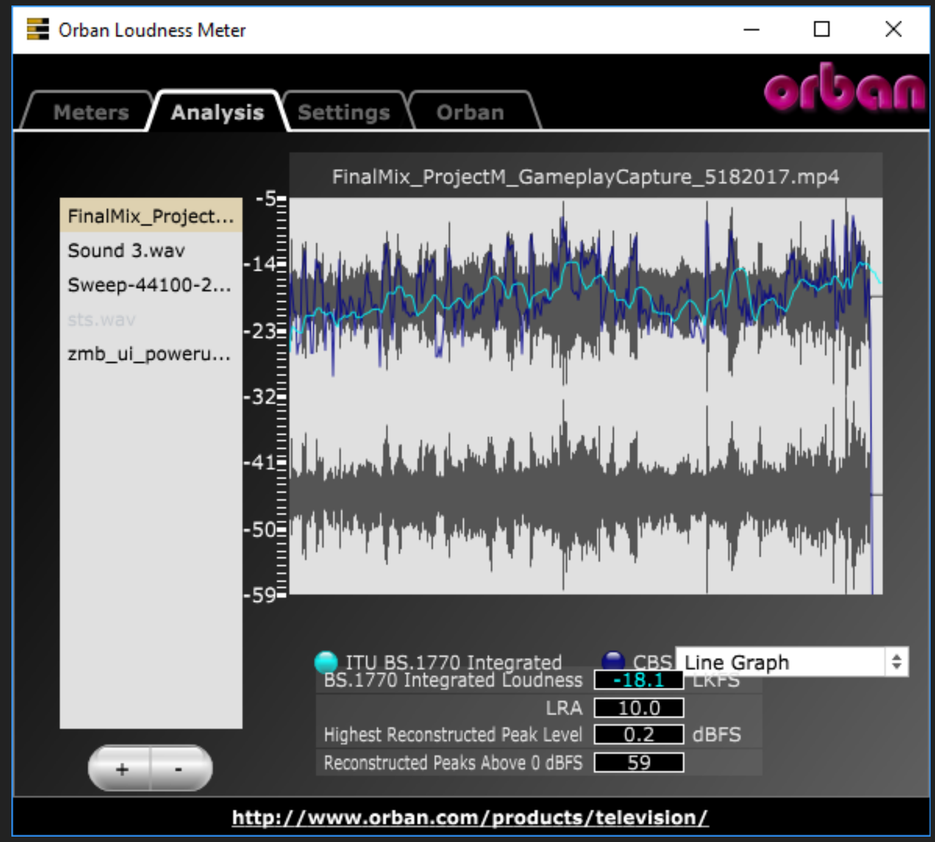
Applying contrast and frequency selection concepts

- Use dynamic range to leave headroom for important sounds
- Employ selective side chain ducking for smooth dynamic mixing
- Employ silence and dynamic contrast for key moments
- Employ frequency contrast to draw attention to key moments and dialogue
- Stagger important stimulus to prevent masking and confusion

Improve Your Mixes

LUFS IS NOT ENUF

- Lufs only evaluates perceived volume over time
- Lufs has no concept of an effective mix, contrast, frequency fatigue, focus, or effective use of silence.
- 5D audio meter?

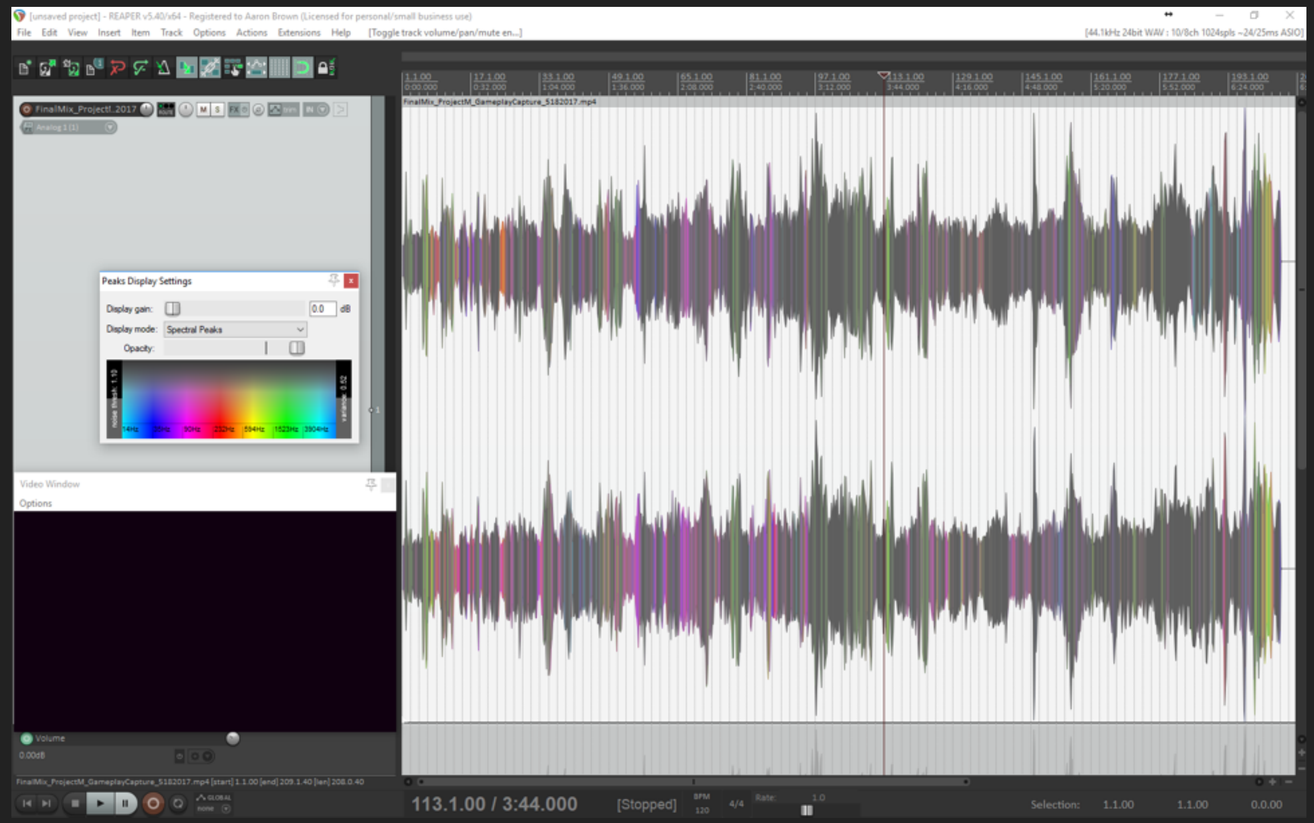


Improve Your Mixes

Reaper - Spectral Peaks

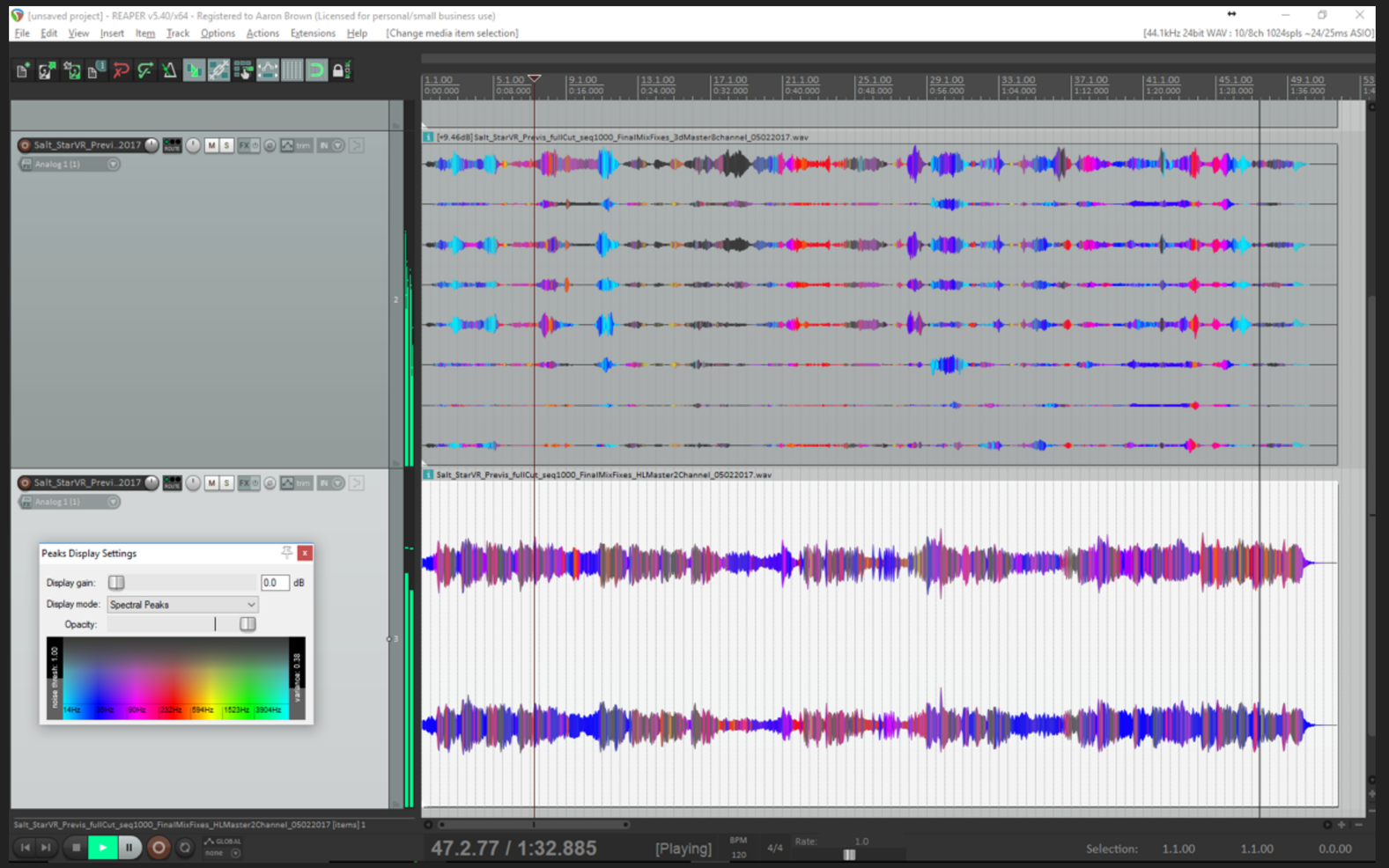
- Spectral peaks shows dominant frequencies over time.
- You can visualize frequency for:
  - Habituation
  - Frequency Masking
  - Check dialogue Freq. of 1-5kHz.
  - Asset contrast

The Mummy Prodigium Strike VR



Improve Your Mixes

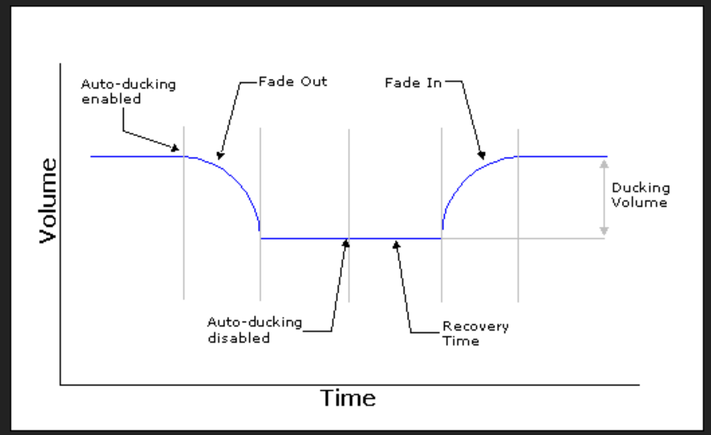
StarVR Salt Conference Demo



Improve Your Mixes

Classic Ducking Techniques

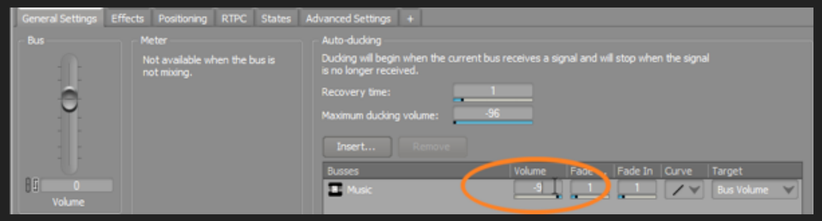
- Traditional Auto-Ducking is TERRIBLE
- Heavy handed and includes silent moments
- Loss of immersion

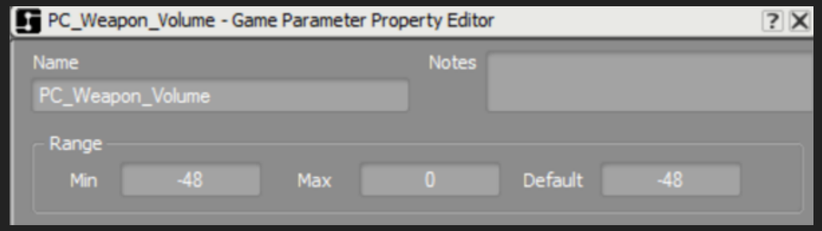


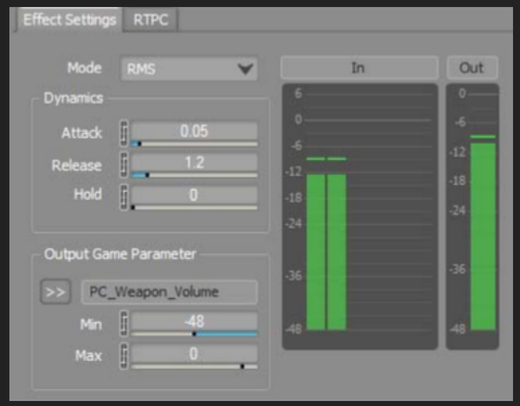
Improve Your Mixes

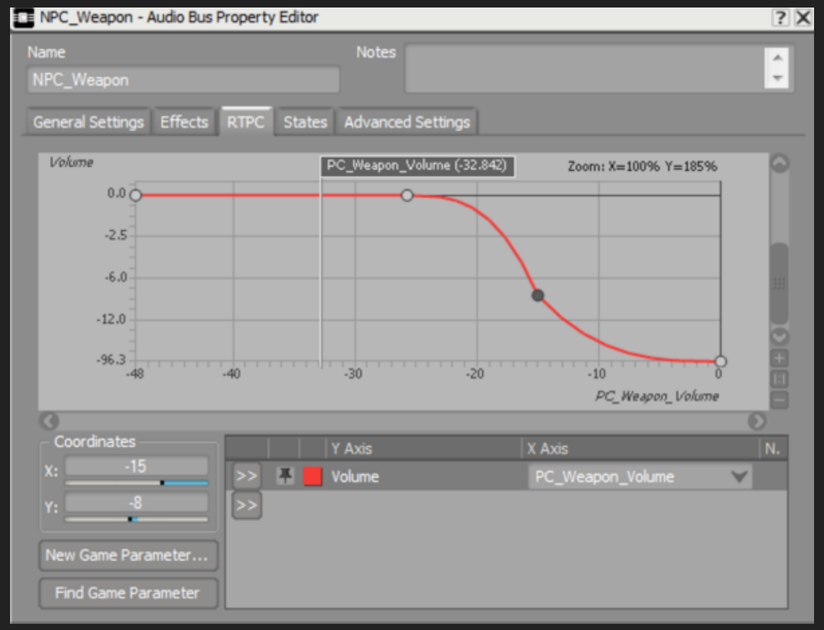
Modern Ducking Techniques

- Sidechain Volume Ducking is GOOD
- Sidechain Volume Ducking selectively is EVEN BETTER







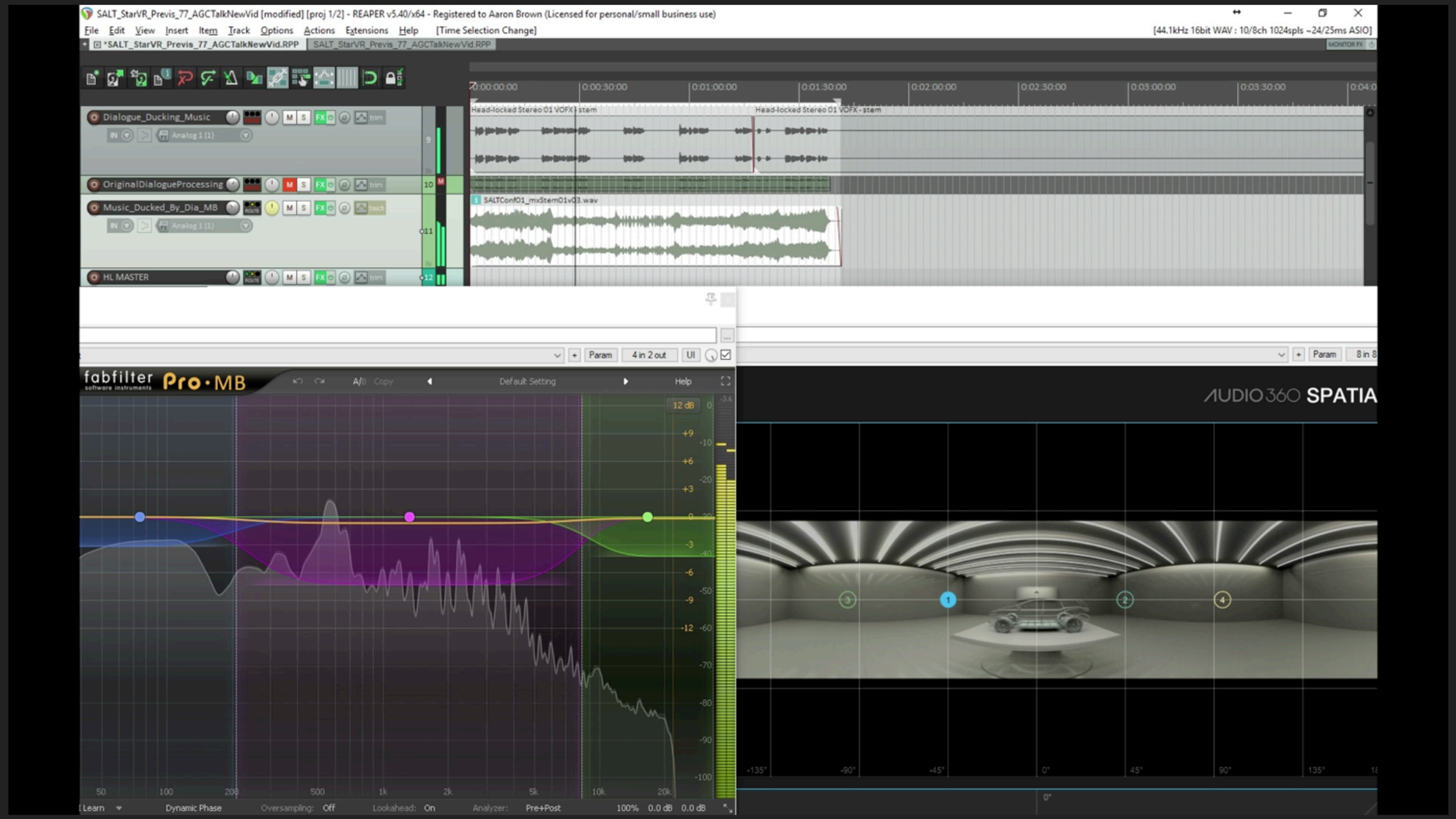


Improve Your Mixes

Modern Ducking Techniques

- Sidechain Ducking selectively using Volume and EQ= EXCELLENT!
- In VR NEVER duck the ambience that provides immersion
    - Motion sickness and loss of immersion

Sidechain Dialogue Ducking - Star Vr



Visual of dialogue ducking music to prevent masking

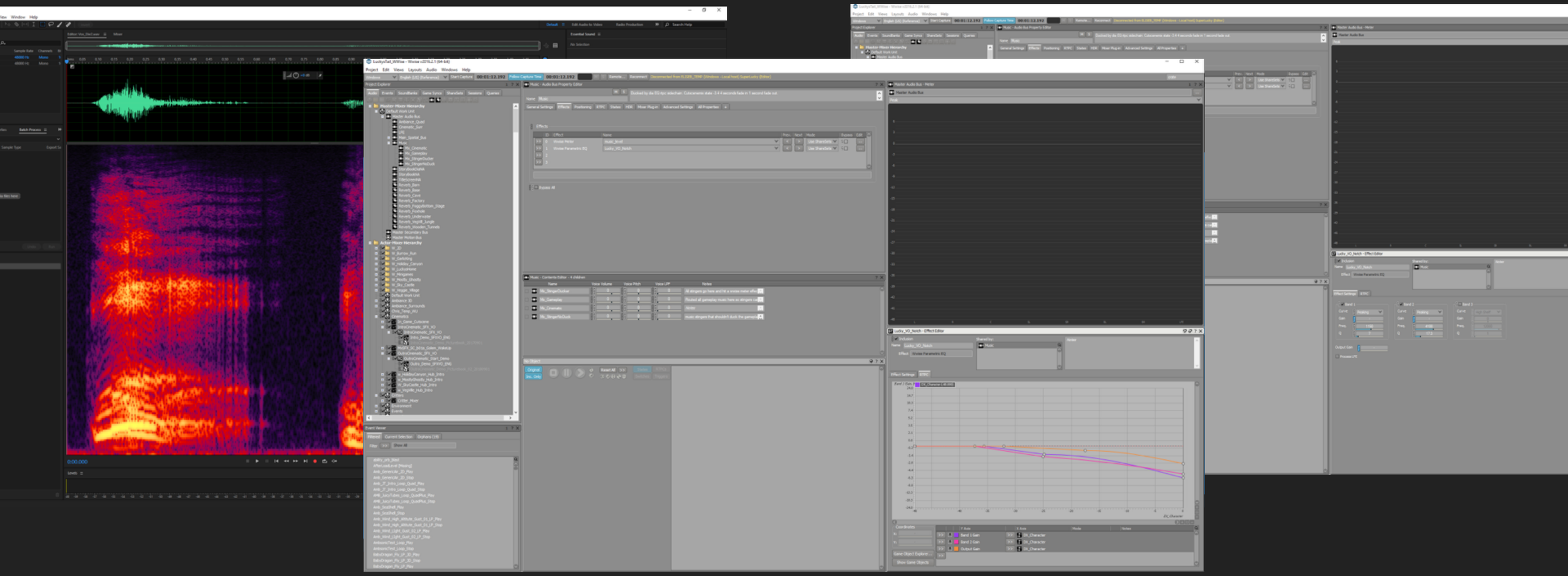
I’m a game audio professional at a game conference, I know how to side chain a compressor in a DAW.

Ducking in Wwise

Wwise Example #1

Live Event Based Ducking

Ducking in Super Lucky's Tale



Microsoft Mix Trick

Sidechain EQ Notching Based on FFT of Peak Frequencies Using Wwise Meter and 3 Band EQ

Improve Your Mixes

Utilize Sidechain Ducking on selective busses

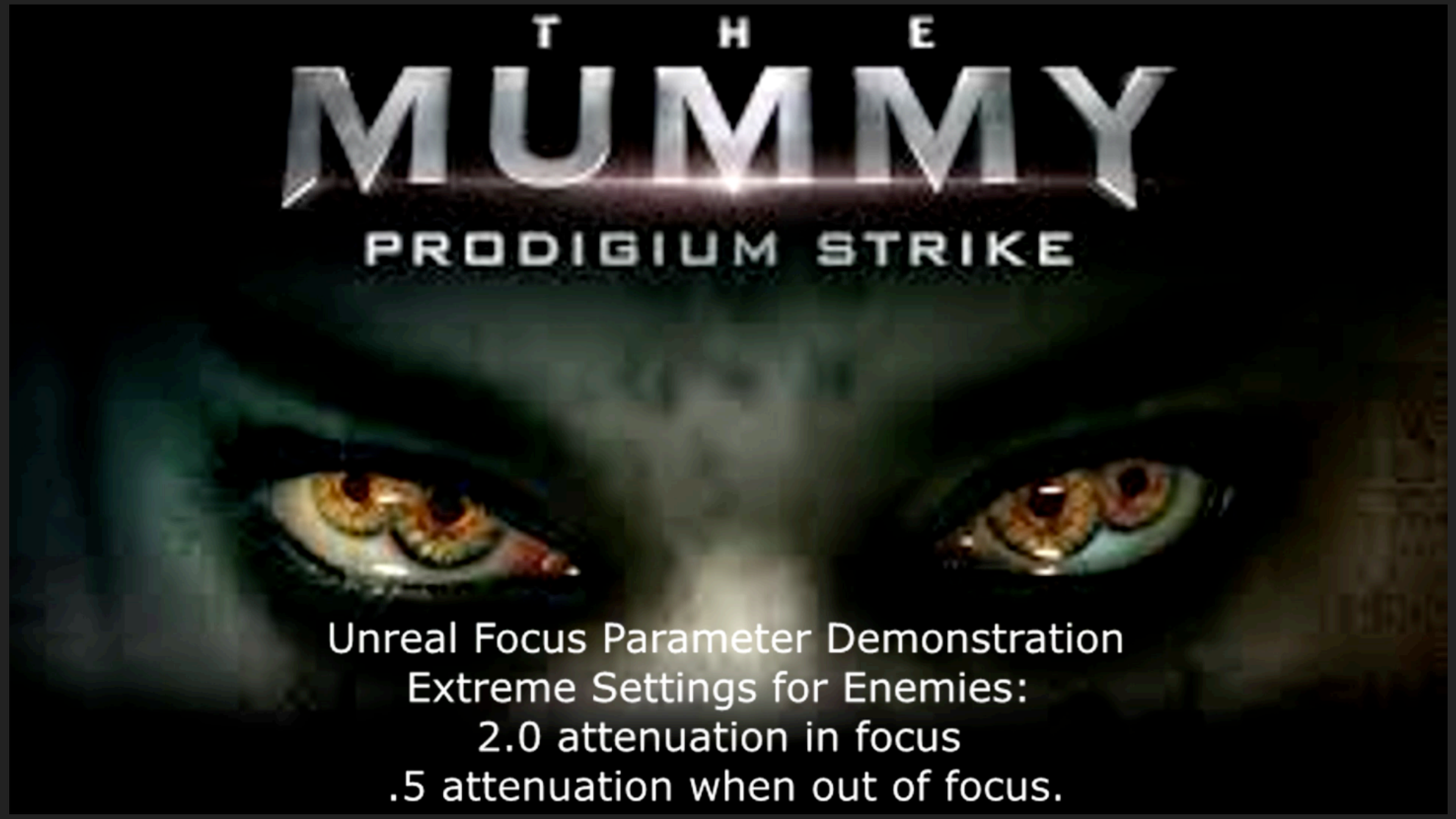
- Maintain Immersion
- Prevent frequency masking
- Increase contrast and focus
- Dynamically improve your mix clarity
- Ensure dialogue intelligibility
- Natural perceptual ducking for busy games
- Wwise using Wwise Meter, RTPCs, EQs, and other parameters.

Improve Your Mixes

Focus Parameter

- Selectively tune sounds based on visual importance
- Visual focus typically matches player importance
- Heighten senses based on tracked player focus in VR space
- Clear sonic clutter when out of focus
- Unreal focus parameter built in tech
- Wwise can do this using an RTPC with Azimuth and applying it using bell curves

Exaggerated Focus Parameter Settings



Extreme Unreal focus settings of 2.0 and .5 attenuation only on enemies just to show focus effect in action.

Low res video from home PC and Unreal Play In Editor

Actual Focus Parameter Settings

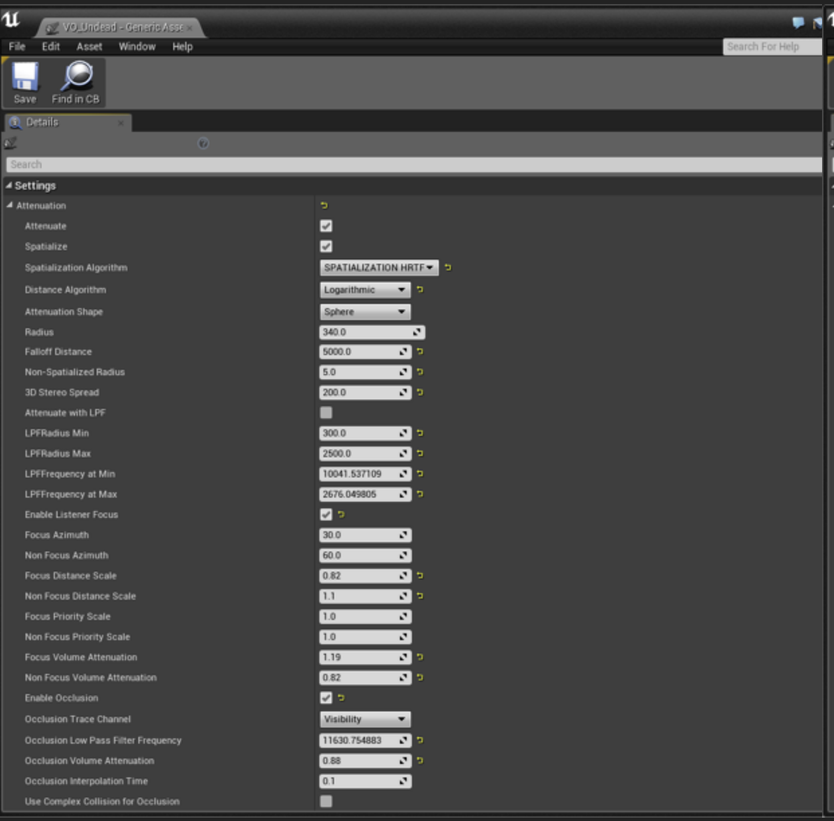
Undead Focus

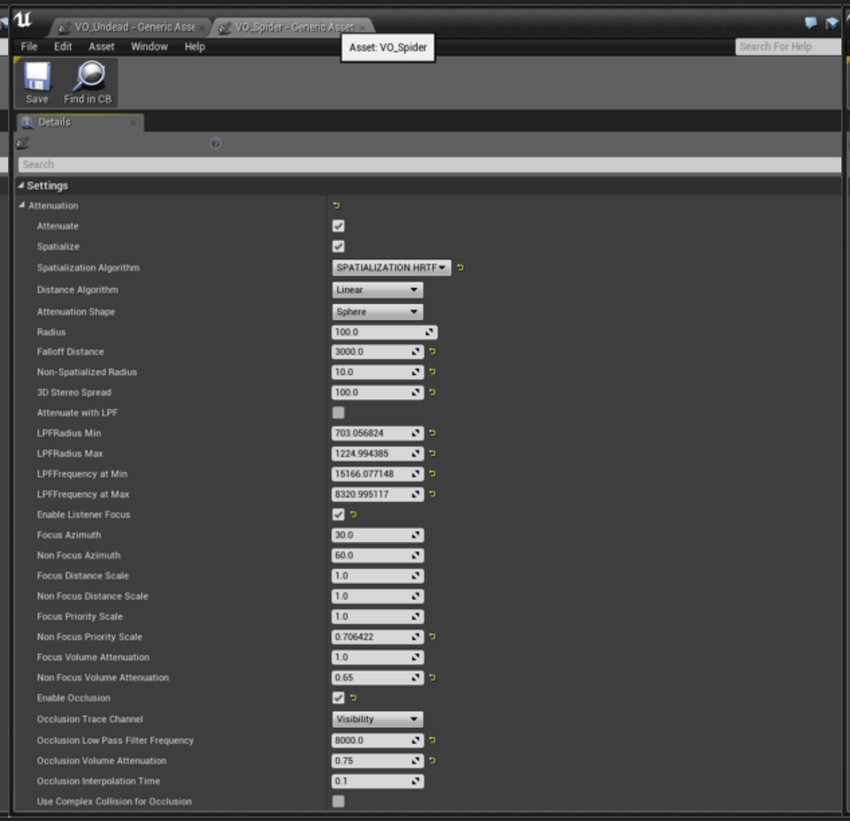
Spider Focus

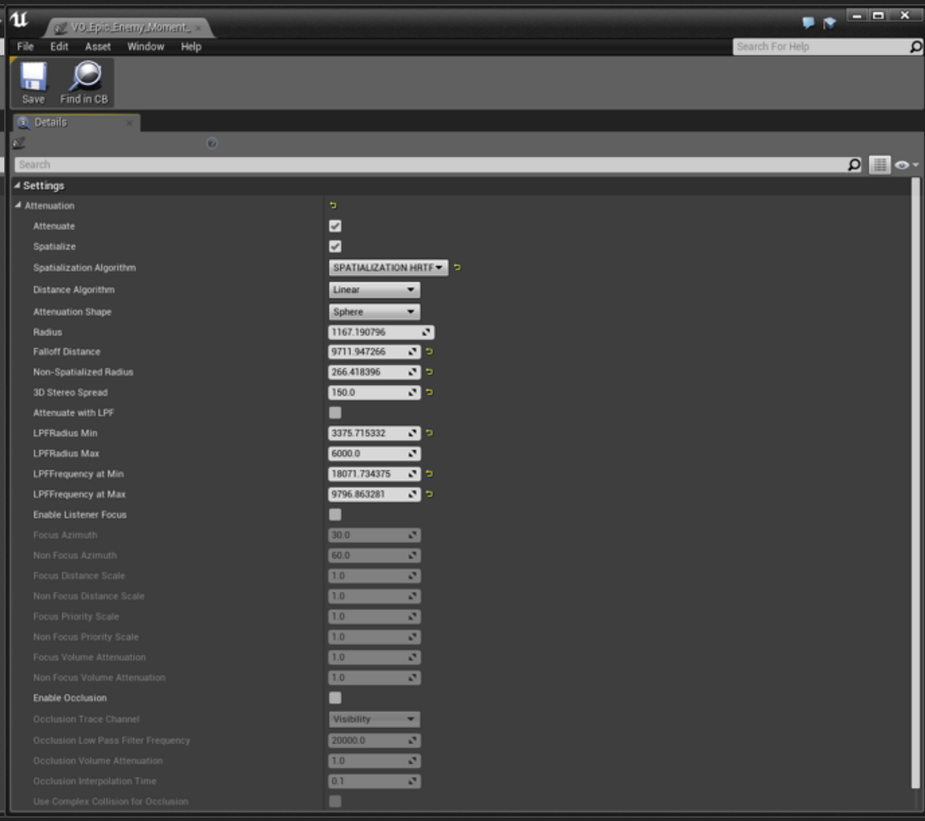
Epic Moment

Unique Attenuation for Unique Animations

to help scare moments stand out using contrast







Focus is best used after a good mix is achieved to subtly heighten focus on important objects.

Improve Your Mixes

SUMMARY

Dynamic Range is a good start, but do a 5D audio check

Stagger Sensory Information where possible

Use focus parameter to dynamically alter player perception and mix

Selectively Sidechain Parameter Ducking > Traditional Ducking

Check your mix using Spectral Peak Analysis in Reaper

IMPROVE IMMERSION

Improve Immersion

ACCURACY IS MORE IMPORTANT THAN EVER

MMN and SSA - The Brains built in QA team

Improve Immersion

MMN -Mismatch negativity - is evoked by unexpected sounds embedded in a stream of expected sounds.

MMN is unconsciously invoked through poor variation settings, incorrect physics sounds, silent interactions and breaking patterns

When patterns are unintentionally broken, player immersion is broken.

Improve Immersion

SSA - Stimulus specific adaptation. Midbrain and cortex habituation that causes common tones to be habituated and variations to cause more attention!

Neurons tire of overly repetitive tones, but perk up to rare stimulus.

When rare stimulus is unintentional it causes improper player focus.

Improve Immersion

To maintain Immersion in VR sound must be accurate and consistent.

Inconsistencies in expectations break immersion

MMN can break immersion in as little as 150 milliseconds

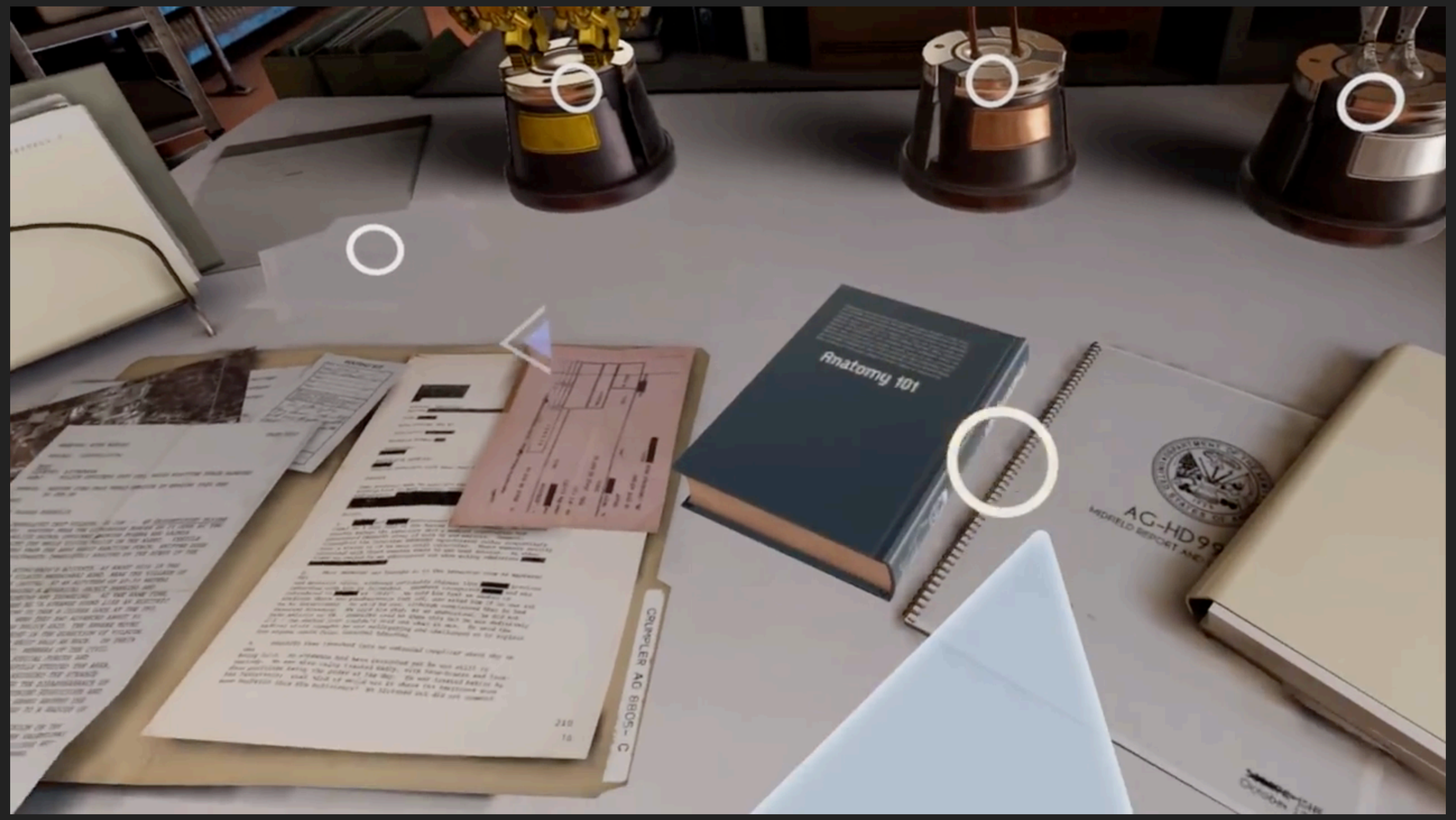
SSA can break immersion in as little as 30 milliseconds

Improve Immersion

Physics

- If the player CAN mess with objects…. they WILL!
- Unrealistic to expect perfect realistic physics sounds on every object in every game
- Set the rules of the world and stick to them consistently
- Any inconsistencies trigger MMN and SSA instantly breaking immersion.

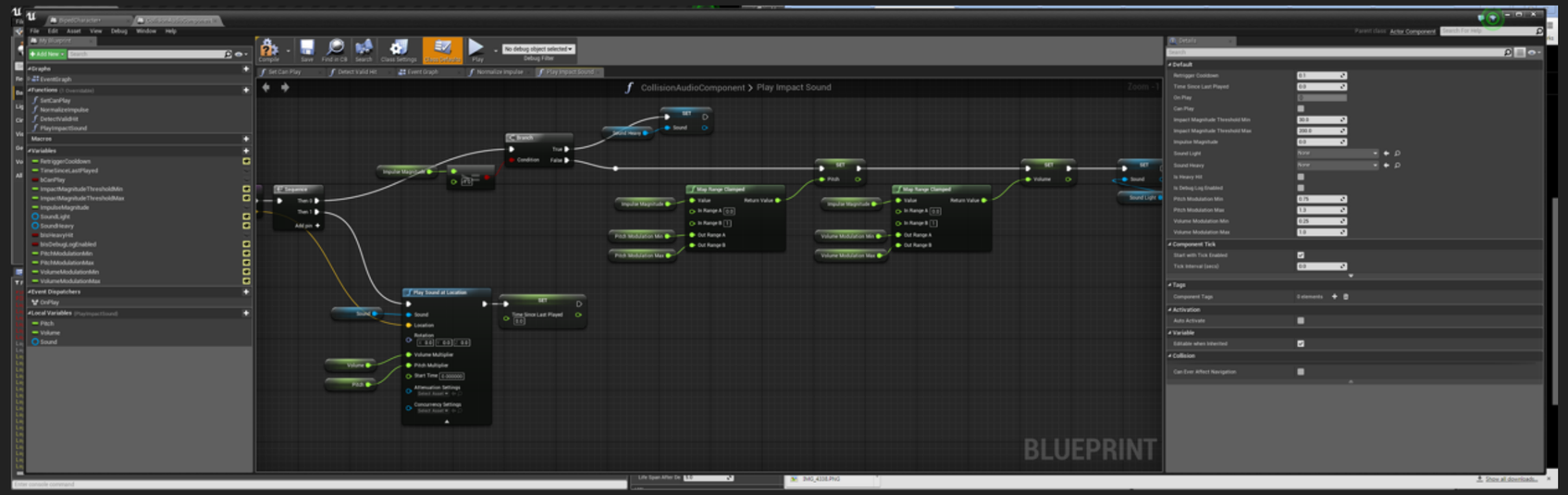
Improve Immersion - Robo Recall Physics



Improve Immersion

Physics

- All inter-actable objects consistent
- Light and Heavy variations, Pitch and Volume Curves, Grab and drop sounds.
- Unreal has made Robo Recall free to download and see these systems in action



Improve Immersion

SUMMARY

Maintaining immersive sound environments is critical

Static ambient beds should be predictable to not draw attention

Avoid MMN by being consistent with the rules of your game’s audio

A 10% increase in volume draws attention to sounds

Unexpected stimuli causes decrease in cognitive performance

ORGANICALLY DRIVE GAMEPLAY

Organically Drive Gameplay

PATTERNS AND REPETITION TRAIN PLAYERS ORGANICALLY

Our brains are pattern seeking machines

This can be used to our advantage.

You can use patterns to draw attention to new sounds in just 150ms.

Using sound patterns gives lots of information without any visual HUD

Organically Drive Gameplay - GETTING “INSIDE” INSIDE

Organically Drive Gameplay

TRAIN THE PLAYER USING HEBBIAN PLASTICITY

Hebbian Plasticity = Neural Learning

Neurons that FIRE together WIRE together - Donald Hebb

No, not a coincedence.

Organically Drive Gameplay

KEY POINTS

USE PATTERNS AND REPETITIVE FREQUENCIES TO TRAIN PLAYERS

BE CAUTIOUS OF HABITUATION

USE MMN TO YOUR ADVANTAGE TO DRIVE PLAYER FOCUS TO NEW PATTERNS

TRIGGER EMOTIONS

Trigger Emotions

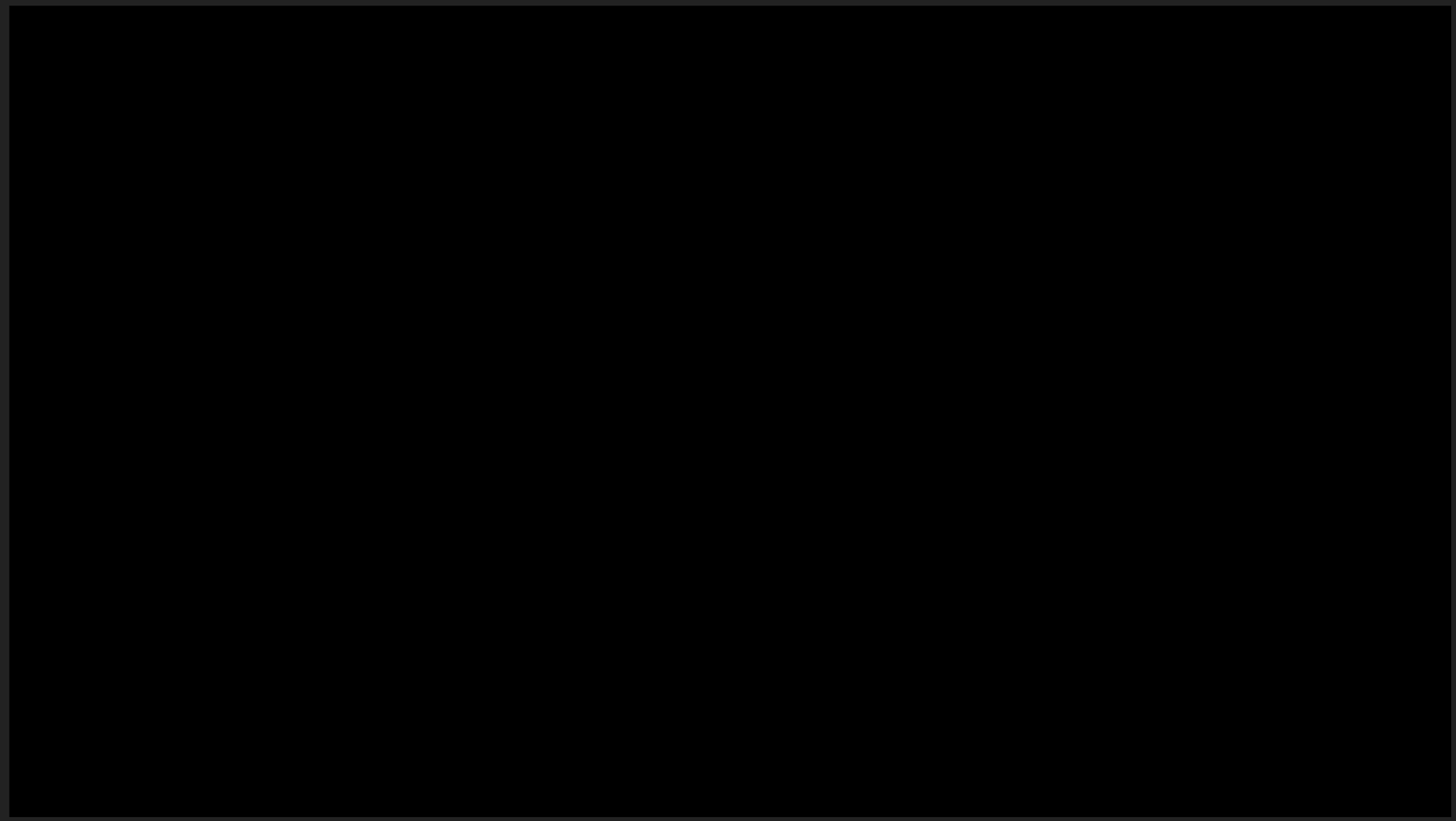
TRIGGERING HUMAN EMOTION

You can get a strong positive emotional response to sounds in less than a second, a brief series of sounds should be sufficient to give you a useful emotional association.

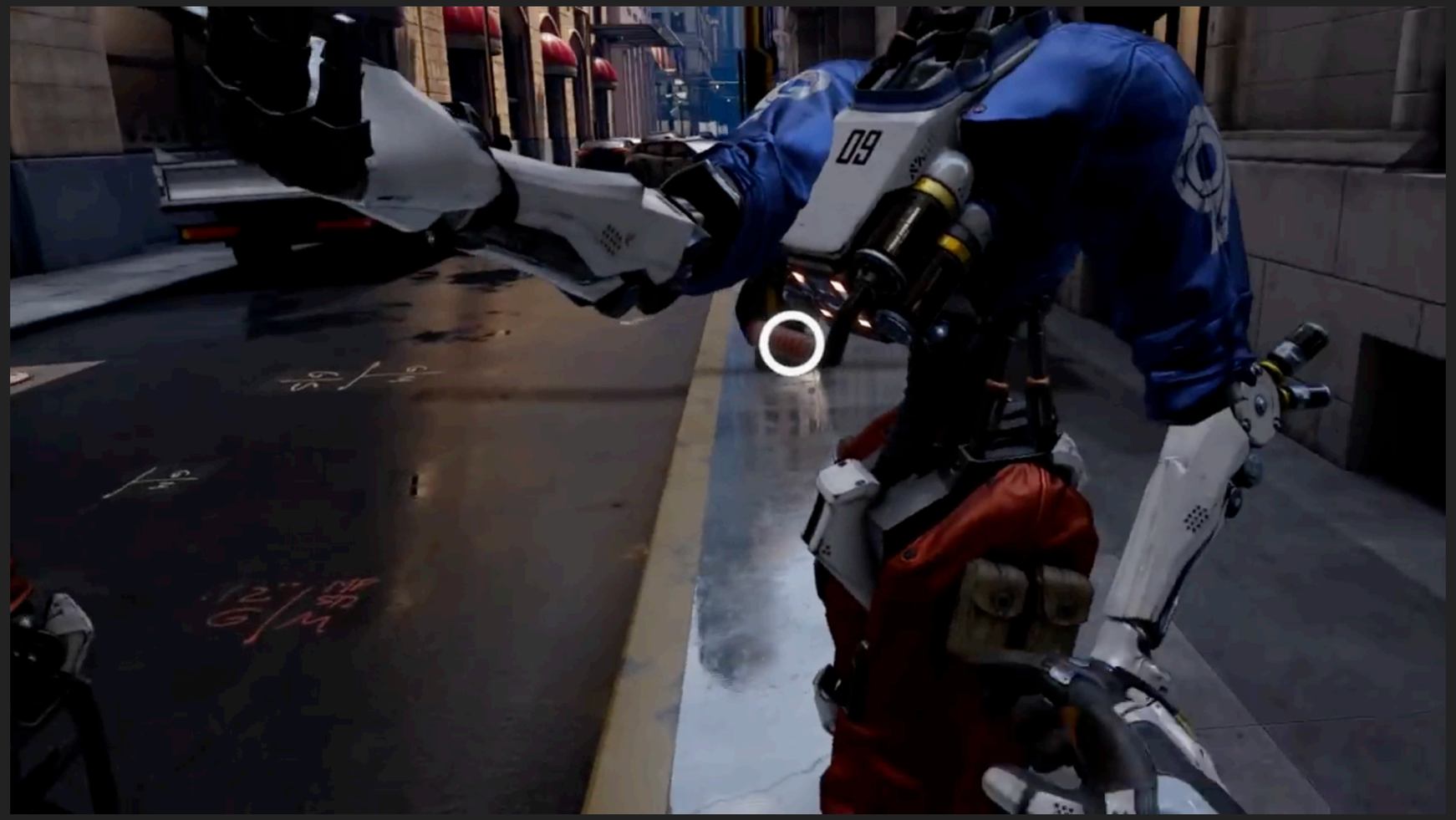
VOICE IS THE MOST POWERFUL EMOTIONAL TRIGGER OF ALL.

Emotional assets draw focus

Trigger Emotions - Robo Recall Only SFX



Trigger Emotions - Robo Recall Voices and Music



Trigger Emotions

FEAR

Save high frequency content in 1-4 kHz. range for scare moments.

Close sounds have more transient attack and high frequencies, the more contrast the scary sounds have the more it will startle the player.

Use the Focus parameter in Unreal to accentuate this effect

Create contrast between distant passive danger and close active threat

Trigger Emotions

Trigger Emotions

KEY POINTS

EMOTIONS CHANGE PLAYER FOCUS AND PERCEPTION

VARY STIMULUS ENOUGH TO PREVENT HABITUATION AND MAXIMIZE RESPONSE

USE VOICE MAXIMIZE EMOTIONAL RESPONSE

LEAVE HEADROOM FOR HIGH CONTRAST SCARE MOMENTS

5D Audio Summary

5D Audio

5D Audio Concepts

Summary of concepts

- WE EXIST IN A SLICE OF 3D SPACE, 4D TIME & 5D CHOICE
- **OUR BRAINS ARE PATTERN SEEKING MACHINES**
- 5D CHOICE RELIES ON FOCUS
- FOCUS IS DRIVEN BY CONTRAST, FREQUENCY MEMORY, AND PATTERNS
- PLAYER PERCEPTION CHANGES OVER TIME BASED ON WHAT'S IMPORTANT
- BRAIN CAN "TUNE IN" OR "TUNE OUT" SOUNDS OVER TIME
- THE BRAIN AND AUDITORY SYSTEM ARE ALWAYS SUBCONSCIOUSLY RUNNING
- PLAYERS CAN BE TRAINED THROUGH SOUND

5D Audio Applications

How to use 5D audio techniques to enhance your experience

- Drive Player Focus and Choice Using Contrast and Frequency Selection
- Improve Your Mixes and Immersion Using Contrast and Frequency Selection
- Use Sidechain Ducking Selectively with Multiband EQ and Volume
- Use focus parameters to dynamically tune the mix based on visual importance
- Check mixes in Reaper using Spectral Peak mode for frequency issues
- Be consistent with your games sound across asset types
- Stagger Sensory Input To Maximize Impact and Focus
- Use patterns and repetition to drive player decisions
- Use human voice and varied stimulus to trigger emotions

5D Audio in VR

Expanding 3D audio to enhance VR experiences using higher dimensions of sound

Go forth and hack your player's brains using sound!

Applause

Aaron Brown

Website: http://www.AaronBrownSound.com

RESOURCES

Horowitz, Seth - The Universal Sense How Hearing Shapes the Mind

King, Andrew J. - Auditory Neuroscience: Making Sense of Sound (MIT Press)

Brain Facts, a primer on the brain and nervous system

https://developer.oculus.com/documentation/audiosdk/latest/concepts/audio-intro-localization/

https://en.wikipedia.org/wiki/Auditory_masking#cite_note-Moore_1995-4

https://auditoryneuroscience.com/topics/basilar-membrane-motion-4-bachs-tocata-fugue

http://howyourbrainworks.net/

https://www.facebook.com/groups/SpatialAudioVRARMR/

https://www.facebook.com/groups/wwisewwizards/

Imagining the 10th dimension - https://www.youtube.com/watch?v=JkxieS-6WuA

Epic Games for kindly allowing me to show clips of Robo Recall

Starbreeze for kindly allowing me to show StarVR clips of The Mummy: Prodigium Strike and Salt VR

Martin Stig Andersen and the Playdead team for letting me show clips of Inside

Davey Wreden for allowing me to show edited clips of Stanley Parable

My amazing girlfriend Hannah who patiently listened to me blabber on about 5D audio for hours and hours and hours…