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Replayable Cooperative Game Design: Left 4 Dead

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What is Left 4 Dead?

- Left 4 Dead is a replayable, cooperative, survival-horror game where four Survivors cooperate to escape environments swarming with murderously enraged “Infected” (ie: zombies)





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Left 4 Dead: The Survivor Team





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Left 4 Dead: Enraged Infected Mob





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Left 4 Dead: The Special Infected





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Left 4 Dead: The Boss Infected





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Left 4 Dead





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Left 4 Dead





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Left 4 Dead





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Left 4 Dead





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Project Goals

➤ Observations

- Perceived Gap in the Market for Co-op gaming
 - The major risk of the project
- Experience creating single player games epic in scale, narrative
- Multiplayer builds community, generates long-term retail sales
 - Still selling Counter-Strike 1.6 today
- Experience with online multiplayer AI technology
 - Counter-Strike Bot

➤ Goal

- Using our AI tech, combine single player and multiplayer game mechanics into a new kind of replayable, cooperative, online experience



Strategy for Reaching our Goals

➤ Require Cooperation

- Primary product risk
- Crisp focus
 - Generate clear data on demand for feature
 - Explicitly fill perceived gap in market
- Game design must clearly encourage coop to mitigate risk

➤ Replayability

- Game design must encourage long-term replayability
- Build online community
- Entertainment as a Service



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Left 4 Dead Game Mechanics

- **Requiring Cooperation**
- **Replayability**
 - Designing for Dramatic Potential
 - Dramatic Anticipation
 - Structured Unpredictability
 - Adaptive Dramatic Pacing
 - Procedurally Populated Environment





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Requiring Cooperation

- **Encourage cooperation throughout game design**
 - Structure game so players *want* to do the right thing
 - Ensure cooperation is the only winning strategy
 - Treat entire Survivor team as “the player”
- **Penalize non-cooperative behavior harshly**
 - Abandoning the team = death
- **Avoid artificial/arbitrary enforcement**
 - Players rebel against overtly heavy-handed punishments
 - No invisible leashes, teleporting stragglers closer, dealing “out of bounds” damage, etc



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Requiring Cooperation

- Survival Horror genre is an excellent fit
 - Well established mainstream genre
 - Everyone knows “The Rules”:
 - The Good Guys work together
 - The Jerks selfishly abandon the group (and die horribly)
 - The Enemies are ruthless and nearly unstoppable



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Requiring Cooperation: Enemy Design

- **You Are Clearly Outnumbered: The Horde**
 - Obviously too many enemies for one Survivor to handle alone
 - “Grabby” Infected stop Survivors when they hit, making even a single Infected dangerous
 - Enforces cooperation in an implicit manner without seeming heavy-handed because it fits the expected genre behavior





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Requiring Cooperation: Enemy Design

➤ Don't Go Out Alone: The Special Infected

- Tougher Infected with special abilities
- Adds a layer of variation to the homogeneity/predictability of battling the horde
- Each special ability exists to address specific gameplay issues
- Each has an overwhelming or incapacitating attack which create dramatic cooperative moments for the Survivor team



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Requiring Cooperation: Enemy Design

➤ The Hunter

- Purpose: Outrun and kill stragglers and “lone wolf” players
- Completely incapacitating Pounce attack





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Requiring Cooperation: Enemy Design

➤ The Smoker

- Purpose: Pull apart tightly coordinated teams to create unexpected moments of chaos
- Completely incapacitating long range Tongue attack





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Requiring Cooperation: Enemy Design

➤ The Boomer

- Purpose: Break the rule of “shoot everything that moves”, forcing players to think a bit before firing
- Boomer’s Vomit/Explosion creates excellent moments of Dramatic Anticipation where you know the mob is coming to get *you*, soon...





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Requiring Cooperation: Enemy Design

- **The Special Infected Incapacitating attacks**
 - Make players fear becoming separated from the group, reinforcing team cohesion
 - Give players near the incapacitated victim the opportunity to be the hero and save them
 - Players really enjoy helping each other



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Requiring Cooperation: Enemy Design

➤ "OH \$#*!!": The Boss Infected

- Boss Infected force the Survivors to immediately reevaluate their tactics
- Breaks Survivor team out of their familiar pattern of behavior
- Forces the Survivors to re-think whole-team situation and current strategy, encourages team talk
- Generates Dramatic Anticipation



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Requiring Cooperation: Enemy Design

➤ The Tank

- Halts forward momentum while Survivors focus on the imminent danger of the Tank
- Requires full attention of entire team
- Forces Survivors to defend instead of assault
- Tank throw ability makes Survivors reevaluate their environment
- Music change, Tank's yells and heavy footfalls create powerful moment of Dramatic Anticipation





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Requiring Cooperation: Enemy Design

➤ The Witch

- Breaks the rule of “shoot everything that moves” with higher contrast than the Boomer
- Forces Survivors to move stealthily and take extra care with flashlights and weapons
- Danger is communicated by broadcasting Witch presence via disturbing crying sound effects
- Creates powerful moments of Dramatic Anticipation





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Requiring Cooperation: Vocalizations

- Survivor characters automatically emit various vocalizations
 - Improves situational awareness
 - "Behind you!"
 - "Hunter's got Zoey!"
 - "Witch!"
 - "Here they come!"
 - "Grenade!"
 - Rebukes for friendly fire
 - Communicates short term goals
 - "The subway is just up the street"
 - "Can you let me out? I'm stuck!"
 - "Get to the chopper!"
 - Encourages cooperation via baseline of camaraderie
 - "Thanks for that"
 - "Don't worry I got ya..."
 - Friendly, supportive tone of voice (usually)

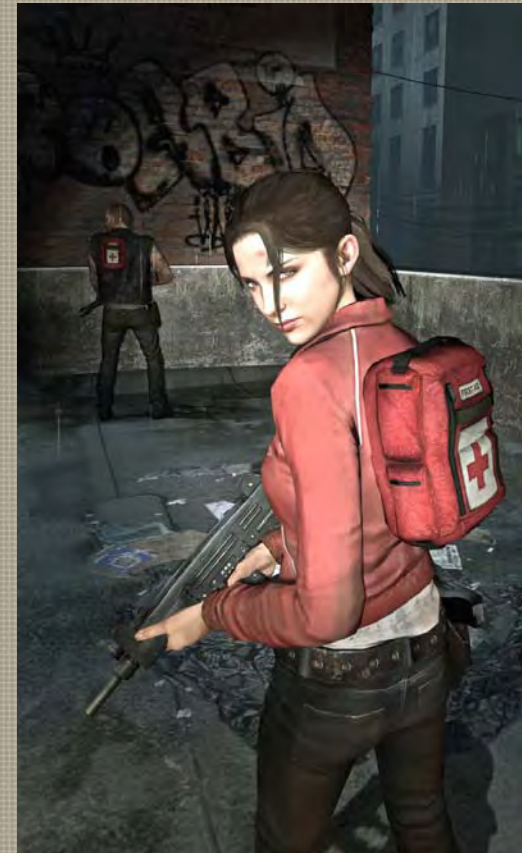




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Requiring Cooperation: Limited Resources

- Limited resources that are required for success encourage cooperation
 - Effective because the game clearly can't be won alone
 - Obvious benefit to sharing (keep extra gun alive)
 - Minimal sharing UI doesn't get in the way
 - Sharing behavior breaks the ice, builds group solidarity
 - Another opportunity for Players to directly help each other





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Requiring Cooperation: Helplessness

- A player in a clearly helpless and dependent state demands cooperation
 - Effective because the game can't be won alone
 - Obvious benefit to sharing (keep extra gun alive)
 - Obvious that you will likely be in a similar situation soon
 - Easy to assist helpless player
 - Benefit clearly outweighs cost (usually)
 - Another opportunity for Players to directly help each other





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Left 4 Dead Game Mechanics

- Requiring Cooperation
- Replayability
 - Designing for Dramatic Potential
 - **Dramatic Anticipation**
 - Structured Unpredictability
 - Adaptive Dramatic Pacing
 - Procedurally Populated Environment





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Designing for Dramatic Potential

➤ Dramatic Anticipation

- Set up moments where event X implies interesting event Y *after a short delay*
- Anticipation of imminent reward/punishment is very powerful
- Example: Old Boomer vs New Boomer



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Designing for Dramatic Potential

- Many Dramatic Anticipation examples in Left 4 Dead
 - Infected Breaking Through Doors
 - Classic horror movie moment of anticipation
 - Boomer Vomit/Explosion
 - A big attack coming in a few seconds. Anticipation enhanced via distinctive music and vision obscuring screen effect
 - Tank Incoming!
 - Distinctive music, Tank's distant yelling and pounding footsteps build anticipation as he approaches
 - Witch Nearby
 - Her sobbing in the distance creates anticipation, particularly when her position is unknown
 - Music
 - Many events are preceded by a distinctive piece of music that builds anticipation
 - Finales/Crescendo Events
 - These start with a angry crowd shrieking in the distance, implying chaos is on the way soon
 - Finale Escape Vehicle
 - Watching the escape vehicle arrive while fighting for your life



Designing for Dramatic Potential

- Dramatic Anticipation examples in Left 4 Dead (continued)
 - Incoming Mobs
 - Seeing a huge mob of Infected running down the street or climbing over a fence
 - “Third Strike”
 - Survivor has been revived twice will die next time – on “last legs”
 - Moving slowly when injured
 - Limping into the safe room with a mob hot on your heels
 - Ledge hanging
 - Classic example of anticipation – the “cliff hanger”
 - Incapacitation
 - Lying helpless and bleeding on the ground generates anticipation for both the victim and his teammates
 - Rescue Closets
 - Hearing trapped friends creates anticipation – especially if you are the only one left alive
 - Car Alarms
 - Double anticipation: Of not setting it off, and of the mob that comes when you do



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Designing for Dramatic Potential

➤ Dramatic Anticipation





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Designing for Dramatic Potential

- **Structured Unpredictability – What is it?**
 - Collections of interesting possibilities selected at runtime using intentionally designed randomized constraints
- **The value of Structured Unpredictability**
 - **Low probability + High drama = Memorable**
 - Designers often want everything to be experienced, every time - resist the temptation
 - Set up many *possible* moments, knowing few will happen at any run
 - Unpredictability greatly enhances replayability and drama
 - Combinations of randomized events generate memorable stories



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Adaptive Dramatic Pacing

➤ Adaptive Dramatic Pacing

- Algorithmically adjusting game pacing on the fly to maximize “drama”

➤ Inspired by Observations from Counter-Strike

- Natural pacing of CS is “spiky”, with periods of quiet tension punctuated by unpredictable moments of intense combat
- Constant, unchanging combat is fatiguing
- Long periods of inactivity are boring
- *Unpredictable* peaks and valleys of intensity create a powerfully compelling and replayable experience
- Same scenario, often the same map, yet different and compelling experience each round



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Adaptive Dramatic Pacing

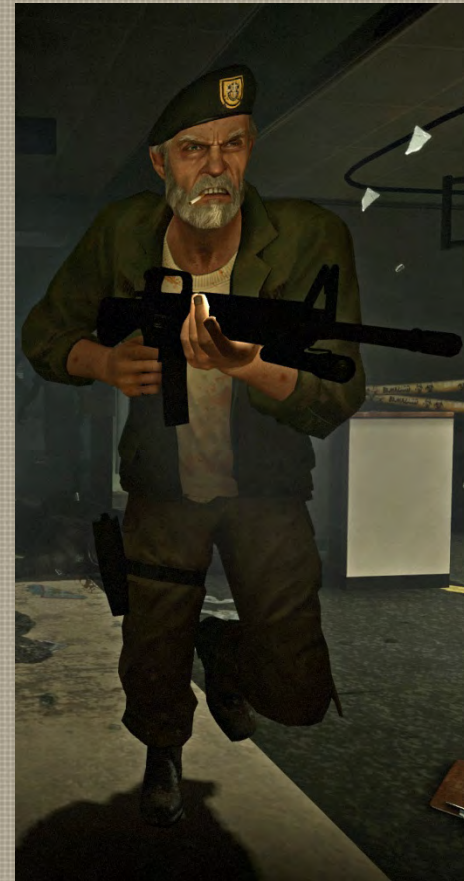
- The AI Director algorithmically drives overall pacing
 - Creates peaks and valleys of intensity similar to the proven pacing success of Counter-Strike
 - Pacing Algorithm
 - Estimate the “emotional intensity” of each Survivor
 - Track the max intensity of all 4 Survivors
 - If intensity is too high, remove major threats for awhile
 - Otherwise, create an interesting population of threats



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Adaptive Dramatic Pacing

- Estimating the “emotional intensity” of each Survivor
 - Represent Survivor Intensity as a single floating point value
 - Increase Survivor Intensity
 - When injured by the Infected, proportional to damage taken
 - When the player becomes incapacitated
 - When player is pulled/pushed off of a ledge by the Infected
 - When nearby Infected dies, inversely proportional to distance
 - Decay Survivor Intensity towards zero over time
 - Do NOT decay Survivor Intensity if there are Infected actively engaging the Survivor





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Adaptive Dramatic Pacing

- Use Survivor Intensity to modulate the Infected population
 - Build Up
 - Create full threat population until Survivor Intensity crosses peak threshold
 - Sustain Peak
 - Continue full threat population for 3-5 seconds after Survivor Intensity has peaked
 - Peak Fade
 - Switch to minimal threat population (“Relax period”) and monitor Survivor Intensity until it decays out of peak range
 - This state is needed so current combat engagement can play out without using up entire Relax period. Peak Fade won’t allow the Relax period to start until a natural break in the action occurs.
 - Relax
 - Maintain minimal threat population for 30-45 seconds, or until Survivors have traveled far enough toward the next safe room



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Adaptive Dramatic Pacing

- **“Build Up” = Full Threat Population**
 - Wanderers
 - Mobs
 - Special Infected
- **“Relax” = Minimal Threat Population**
 - No Wanderers until team is calm
 - No Mobs
 - No Special Infected (although existing Specials may attack)
- **Boss Encounters NOT affected by adaptive pacing**



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Adaptive Dramatic Pacing

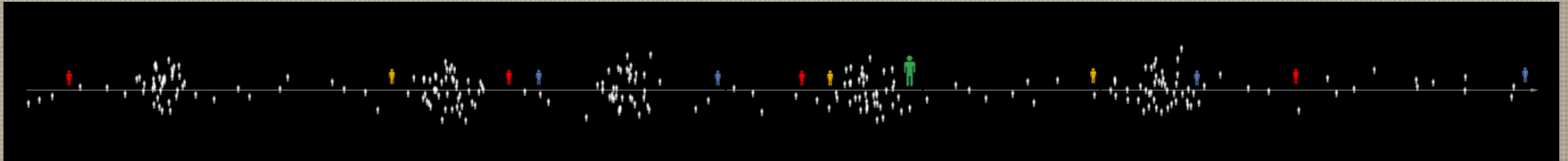
- Adaptive Dramatic Pacing reacts to Survivor team actions
 - Generates reliable peaks of intensity without completely overwhelming the team
 - Because of player variation, timing and location of peaks will differ each time game is played



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Adaptive Dramatic Pacing

- A procedurally generated population

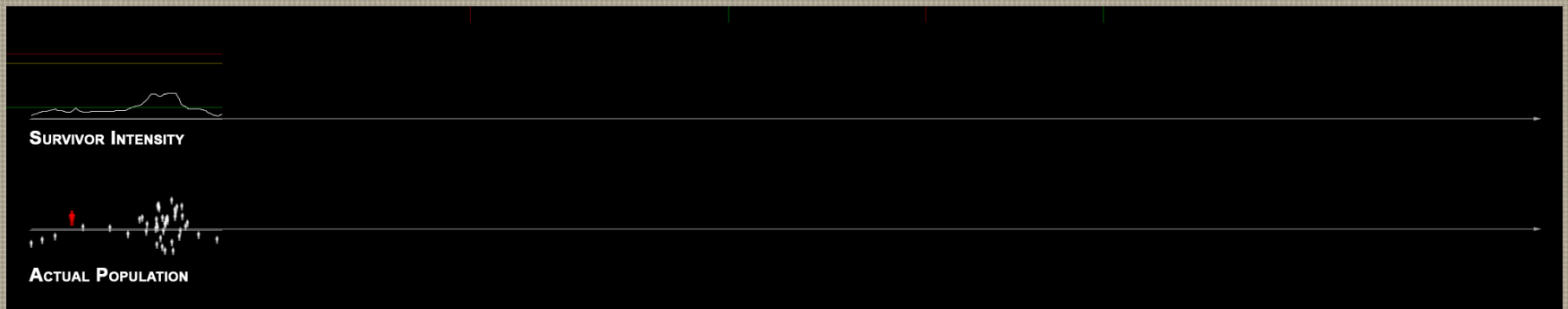




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Adaptive Dramatic Pacing

- How the AI Director modulates the population based on the Survivor team's "emotional intensity"





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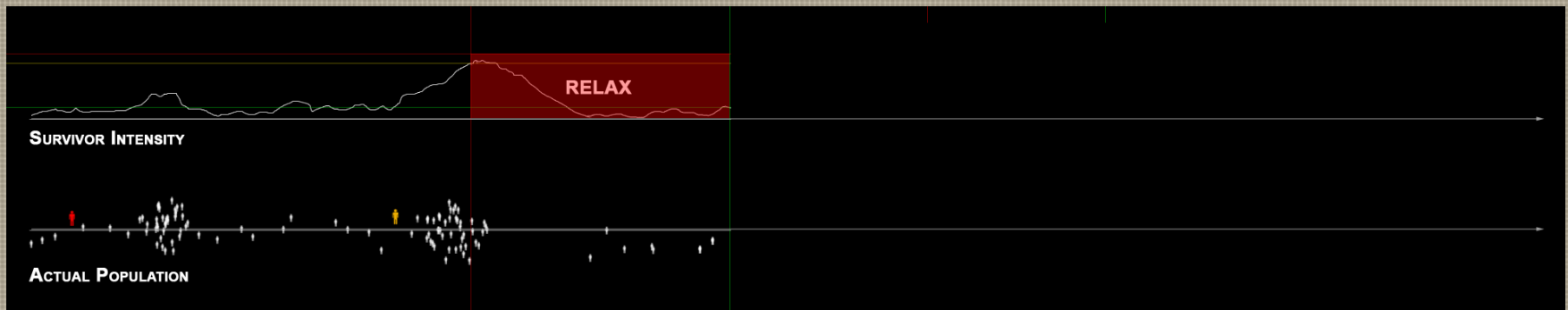




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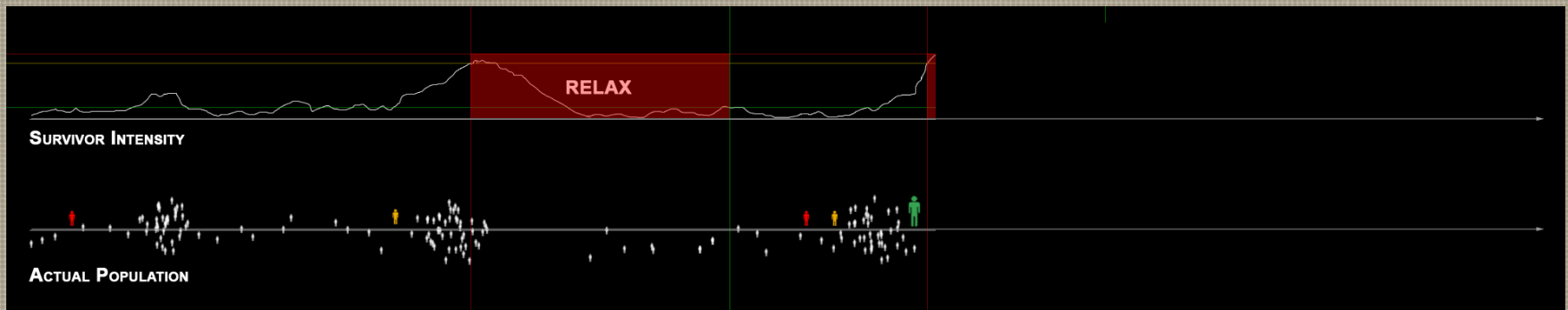




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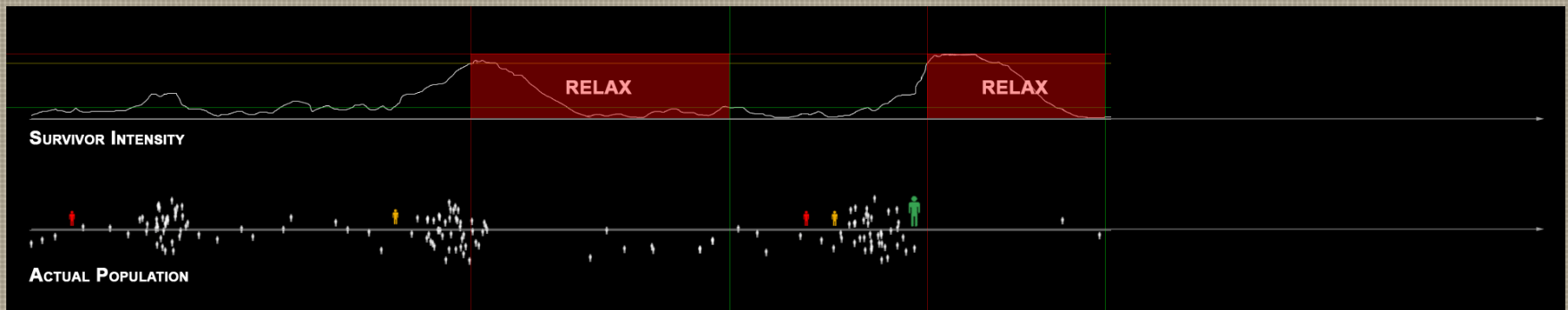




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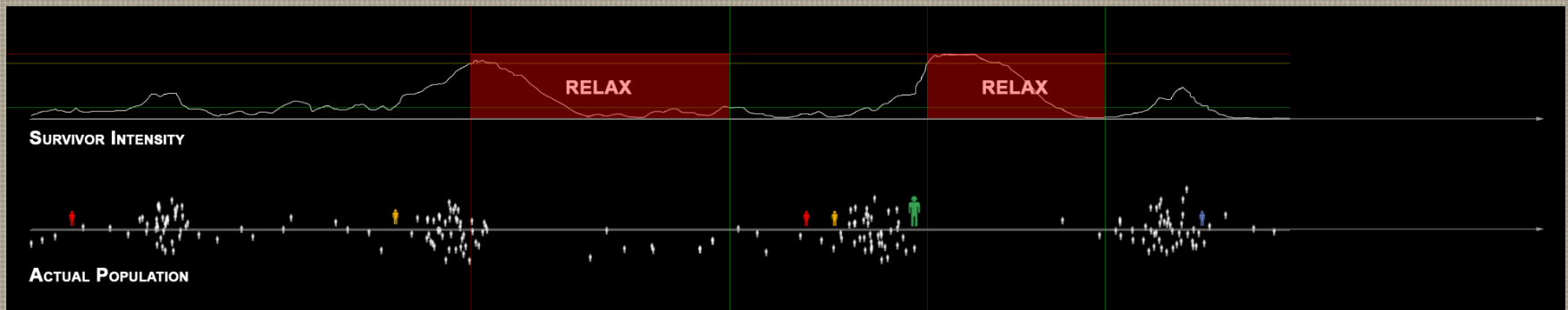




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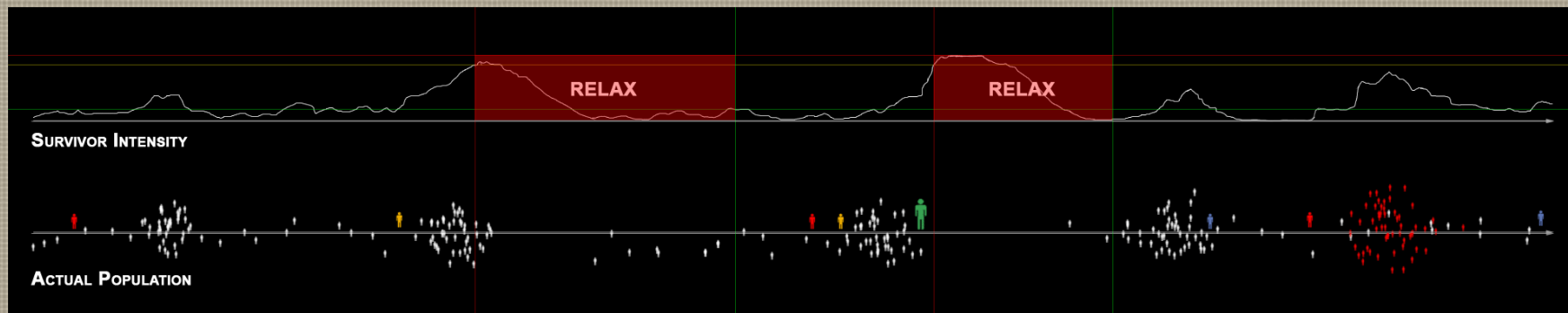




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Adaptive Dramatic Pacing

- How the AI Director modulates the population based on the Survivor team's "emotional intensity"





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Adaptive Dramatic Pacing

- Comparing population after modulation by the AI Director





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 - **Procedurally Populated Environment**





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Procedurally Populated Environment

- How do we fill the environment with interesting distributions of threats?
 - Layers of Structured Unpredictability
- How to populate world with hundreds of enemies efficiently?
 - Reuse a limited number of entities
 - Only populate the environment immediately surrounding the Survivor team via the Active Area Set



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Procedurally Populated Environment

- Layers of **Structured Unpredictability** create interesting populations
 - Wanderers
 - Common Infected that wander around in a daze, sit down, or lay down until alerted by a Survivor
 - Mobs
 - A large group (20-30) of enraged Common Infected that rush the Survivors at unexpected times
 - Special Infected
 - Infected with special abilities that skirmish with the Survivor team periodically
 - Bosses
 - Powerful Infected encountered a few times per map that force the Survivors to change their strategy
 - Weapon Caches
 - Collections of "2nd tier" weapons
 - Scavenge Items
 - Pipe bombs, Molotovs, Pain Pills, Extra Pistols



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Procedurally Populated Environment

➤ The Navigation Mesh

- Originally created for Counter-Strike Bot pathfinding
- Useful for general spatial reasoning and spatially localized information
 - Has an area been seen by an actor?
 - Is area X potentially visible by area Y?
 - "Flow" distance – distance to this area from the Survivor team start location in the map
 - Etc





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Procedurally Populated Environment

➤ The Active Area Set (AAS)

- The set of Navigation Areas surrounding the Survivor team
- The AI Director creates/destroys Infected as the AAS moves through the environment



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Procedurally Populated Environment

➤ The Active Area Set





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Procedurally Populated Environment

➤ The Active Area Set





Procedurally Populated Environment

➤ The Active Area Set





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Procedurally Populated Environment

- **Populating Wandering Infected**
 - Stored as a simple count, C , in each area
 - Counts are randomly determined at map (re)start
 - When an area **enters** the AAS
 - Create C Infected (if possible)
 - When an area **leaves** the AAS, or a **pending Mob needs more members**
 - Wanderers in the area are deleted and C is increased accordingly
 - Wanderer count is zeroed:
 - When an area becomes visible to any Survivor
 - When the Director is in Relax mode





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Procedurally Populated Environment

➤ Populating Mobs

- Created at randomized intervals (90-180 seconds on Normal difficulty)
- No mobs during Relax periods
- Boomer Vomit forces Mob spawn, resets random interval
- Mob size grows from minimum just after spawn to maximum after a duration to balance difficulty of successive, frequent Mobs





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Procedurally Populated Environment

➤ Where to create Mobs

- Behind Survivors
 - Only select valid areas in the AAS that are at or behind the Survivor team's "flow" distance
 - 75% of Mobs come from behind, since wanderers and Special/Boss Infected are usually engaged ahead of the team
- Near Boomer Vomit Victim
 - Only select valid areas in the AAS that are near the Boomer Vomit Victim's "flow" distance
- Anywhere
 - Any valid area in the AAS
 - Default if there are no valid areas in the more specific sets



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Procedurally Populated Environment

➤ Populating the Special Infected

- Created at individually randomized intervals
- No Specials during Relax periods
- Use any valid area not currently visible by the Survivor team
- Cleared status of areas ignored
- Smokers attempt to select areas above the Survivor team



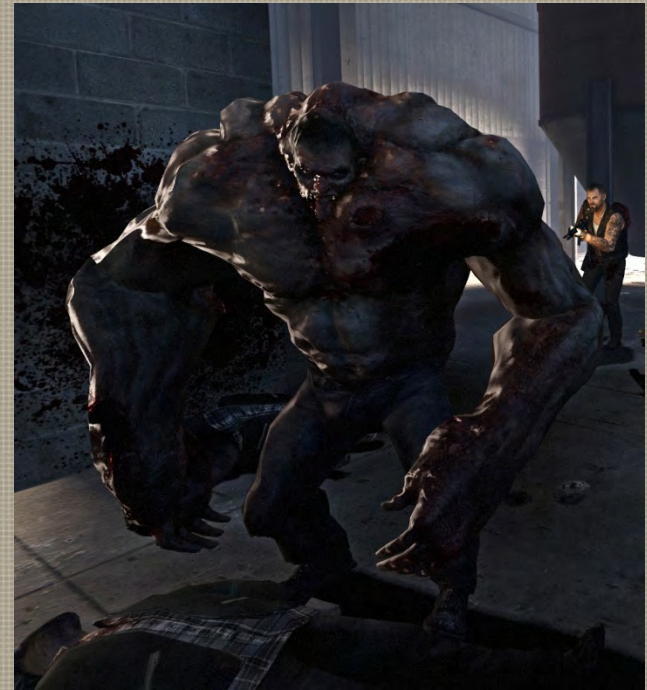


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Procedurally Populated Environment

➤ Boss Population

- Created every N units along “escape path” +/- random amount.
- Three Boss events are shuffled and dealt out: Tank, Witch, and Nothing.
- Successive repeats are not allowed (ie: Tank, then Tank again)



Tank	Witch		Witch		Tank		Witch	Tank
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Procedurally Populated Environment

- Avoid manually placed scripts/triggers
 - Specifically with respect to “when” and “where”
 - “what” can be ok
 - Kills replayability
 - Players learn all script locations quickly
 - Removes suspense of not knowing what will happen next
 - Kills cooperation
 - Players expect everyone to have memorized all encounters
 - Becomes a race



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Procedurally Populated Environment

- **Weapon Caches**
 - Map designer creates several possible weapon caches in each map, the AI Director chooses which will actually exist
- **Scavenge Items**
 - Map designer creates many possible item groups throughout the map, the AI Direction chooses which groups actually exist
- **Why designer-placed?**
 - Prediction of possible locations beneficial in this case
 - Allows visual storytelling/intention
 - Solves item placement issues (leaning against wall, mounted in gun rack, etc)





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Other Supporting Technologies

- **Voice over IP**
 - “Open mic” allows spontaneous and rapid communication
 - Hearing friend’s reactions increases drama and camaraderie
- **Game Instructor**
 - System of hints and visual directives allows new players to learn the game “on the fly”
- **In-game Voting**
 - Allow community to police itself
- **Split screen**
 - Supports casual “living room couch” cooperative play
 - Introduces a friend to the game
- **Achievements**
 - Reinforces desired co-op behaviors
 - Poses challenges for future play sessions
- **Steam/Matchmaking**
 - Friend lists
 - Groups
 - Free weekend passes
 - Matchmaking
- **Robust AI “Actors”**
 - CPU controlled Common, Special, and Boss Infected as well as Survivors



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Robust AI Actors

- A procedural, adaptive system like the AI Director needs a roster of robust AI agents to direct
 - Humans don't like to be explicitly directed (VS mode)
- **Complex 3D Environment Navigation**
 - Climb fences, rubble
 - Use ladders
 - Jump across rooftops
- **Rich Behaviors**
 - Custom HCSM system with integrated event processing
- **Survivor Bots**
 - Allowed us to assume baseline 4 player Survivor team for game tuning
 - Drop in/out ("Take a Break") incredibly valuable in the wild
 - Automated testing



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Summary

- **Random players in the wild will actually cooperate!**
 - If game is structured to facilitate it (ie: no way to win otherwise)
 - Players enjoy helping each other
- **Procedural Content**
 - Generates replayability
 - Solution for replayable multiplayer experiences
 - Greatly multiplies output of development team
 - Improves community created content
- **Dramatic Anticipation**
 - If an event is exciting, it will be more so if it broadcasts its impending arrival
- **Structured Unpredictability**
 - Low probability + High drama = Memorable
- **Simple algorithms can generate compelling pacing schedules**
 - Survivor Intensity estimation is crude, yet the resulting pacing works



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Do These Techniques Work?

- In the six months since release, Left 4 Dead has
 - ... sold more than 2,500,000 retail units
 - ... received over 40 industry awards
 - ... become the #1 new IP on the PC and Xbox 360



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For more information...

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THANK YOU!

