

The Art of Game AI: Sculpting Behavior with Data, Formulas, and Finesse

Dave Mark
President & Lead
Designer
Intrinsic Algorithm LLC

Kevin Dill
R* New England
Blue Fang
Boston University

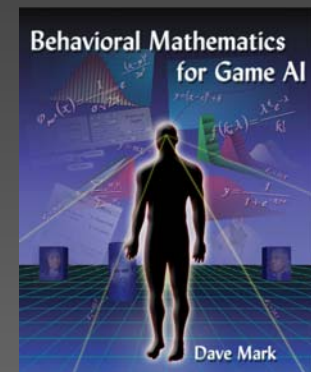
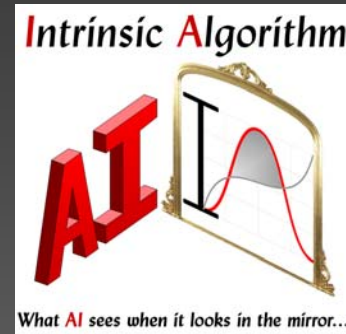


“Reducing the world to mathematical equations!”

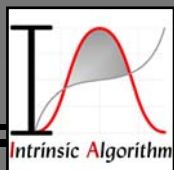


Dave Mark

- President & Lead Designer of Intrinsic Algorithm LLC
 - Game Studio
 - AI Consulting Company
- Author of Behavioral Mathematics for Game AI
- Co-founder of AI Game Programmers Guild
- Organizer and co-host of the AI Summit at GDC 2009 (soon to be 2010!)



AI Summit
GDC 2009



“Reducing the world to mathematical equations!”



Premises/Disclaimers

The examples you will see are only scratching the surface.

There is no way to show concrete implementation in a 1-hour lecture.

We want to make you *think* about what you *can* do.



“Reducing the world to mathematical equations!”



What makes a game a game?



“A game is
a series of
interesting
choices.”

- Sid Meier



“Reducing the world to mathematical equations!”



AI is Your World!

Boring AI = Boring World

Deep AI = Immersive World

Repetitive AI = Monotonous World

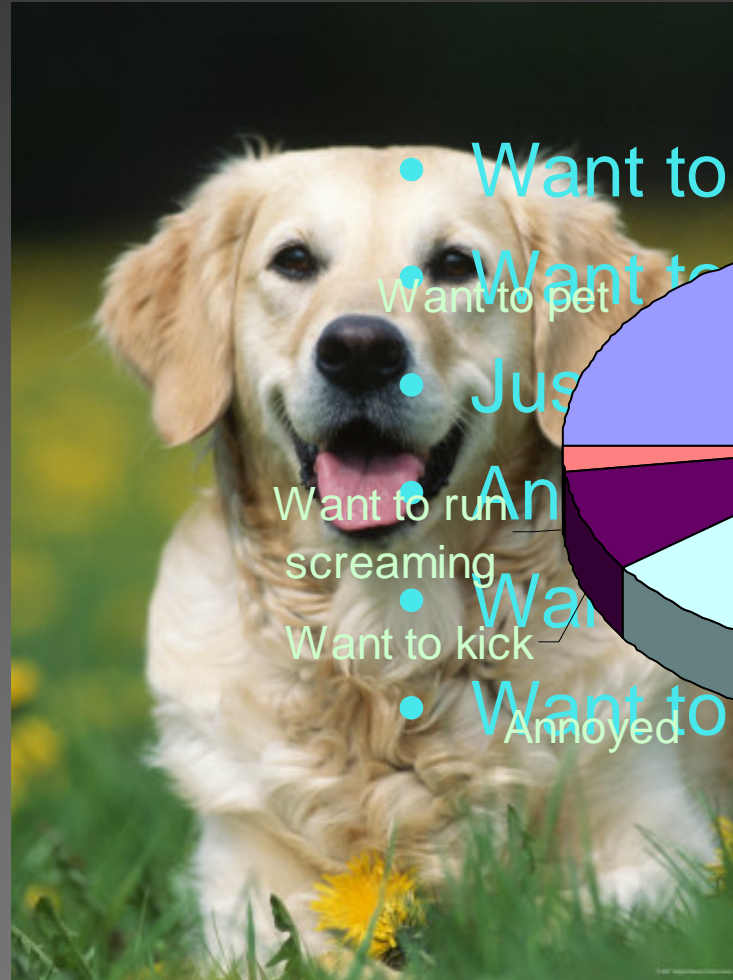
Dynamic AI = Dynamic World



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What is your reaction?



• Want to pet

Want to meet

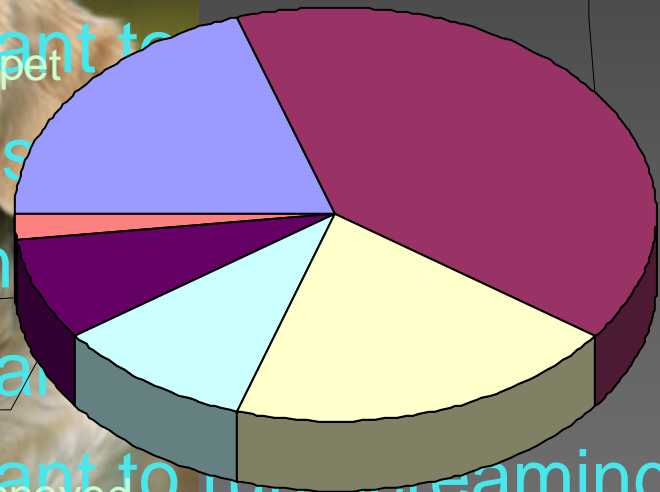
• Want to pet

• Just

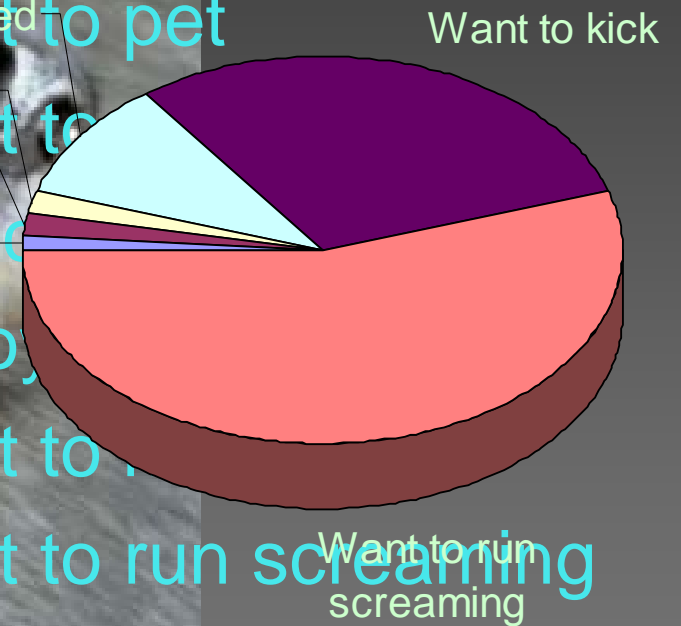
• Annoyed
Want to run screaming

• Want
Want to kick

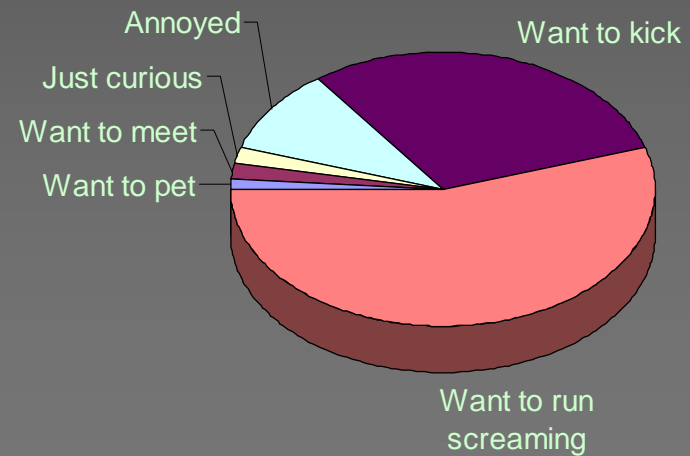
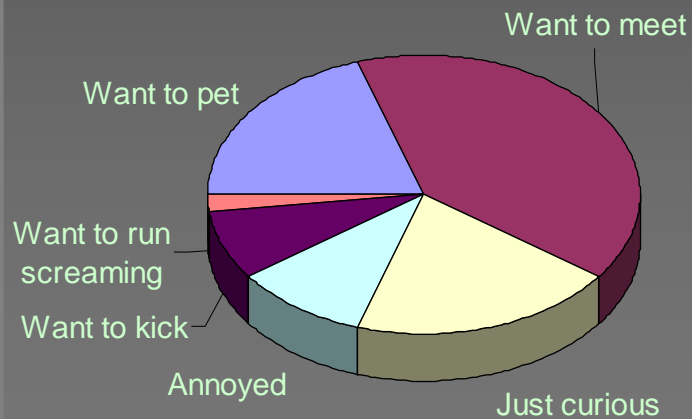
• Want to run screaming
Annoyed
Just curious



Now what is your reaction?



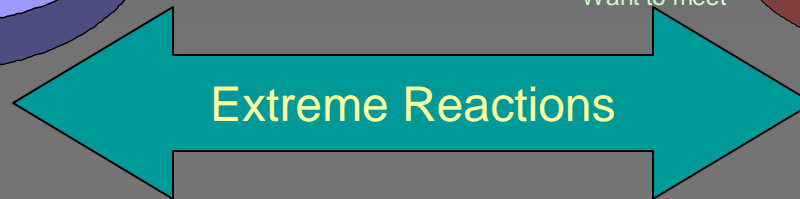
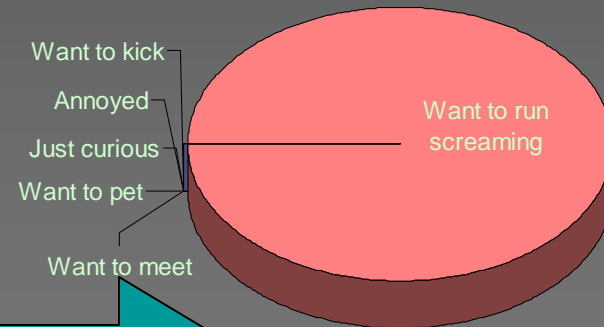
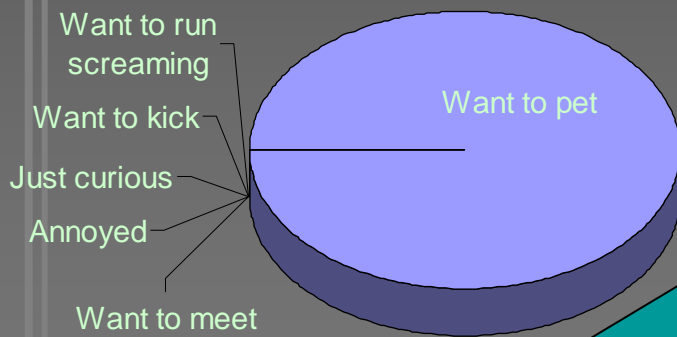
Varieties of Reactions



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Same Model for All Agents



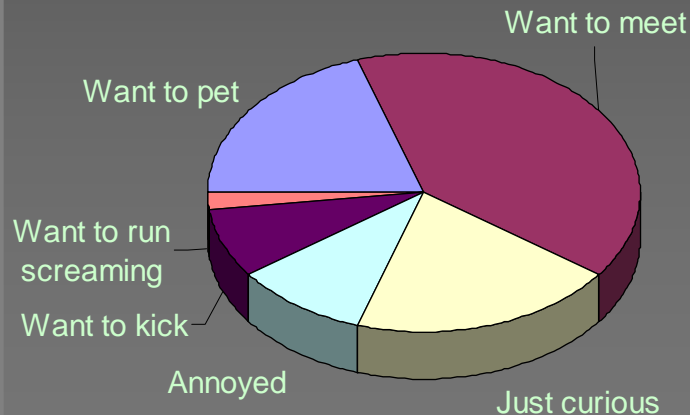
“Reducing the world to mathematical equations!”



Varieties of Reactions



- Differences Exist
- Don't need to know why
- Need to simulate that difference do exist
 - Not completely random selection
 - Must be reasonable



“Reducing the world to mathematical equations!”



How Can We Express Differences?

- Not that information exists (e.g. yes or no) but what that information *says*.
- Identifying more than one factor for input
- Allowing for more than one possible result



“Reducing the world to mathematical equations!”



How Can We Express Differences?

- Not that information exists (e.g. yes or no) but what that information says.
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Processing One Piece of Info

Simple example:

As the distance changes,
how much anxiety do you
have?

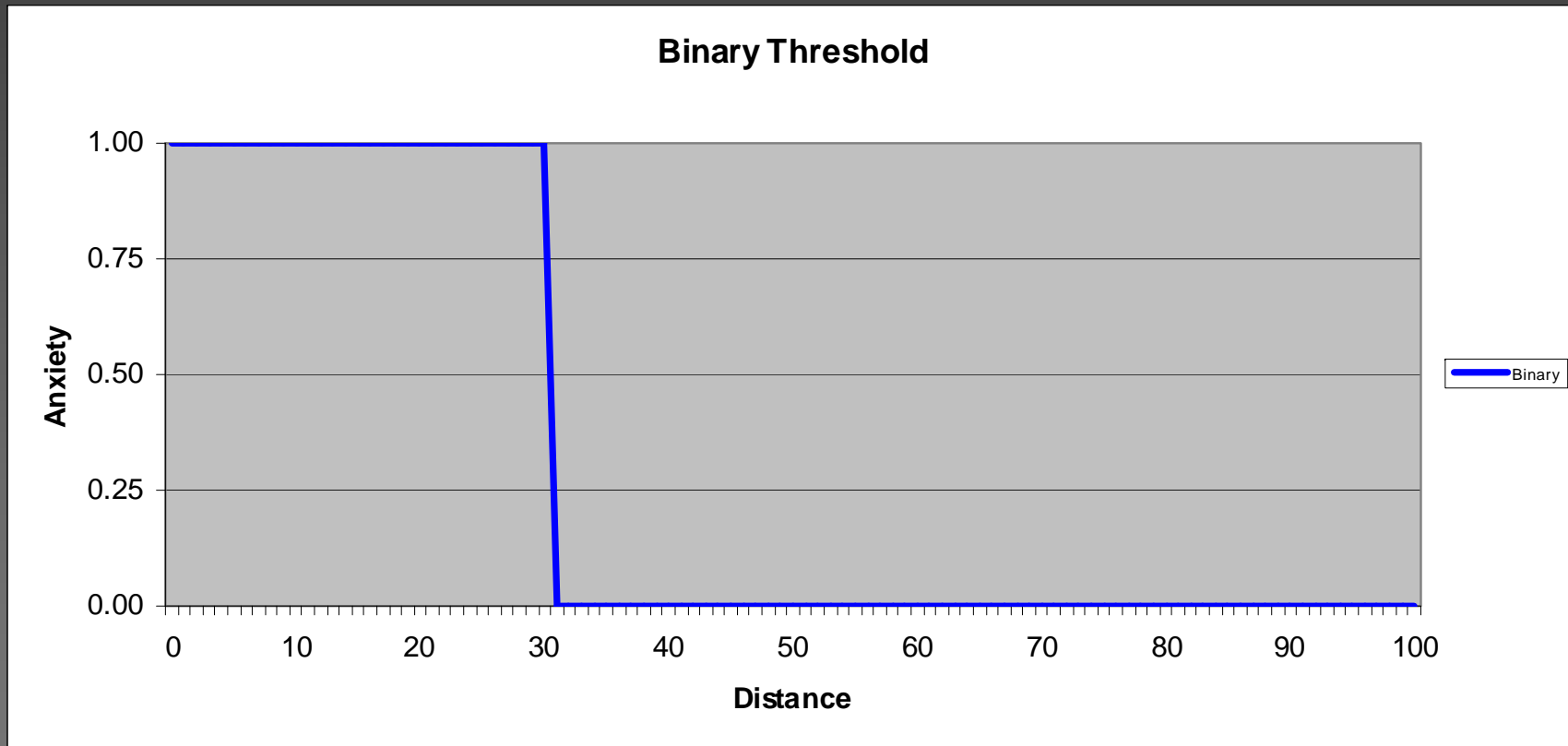


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Simple Rule

If distance ≤ 30

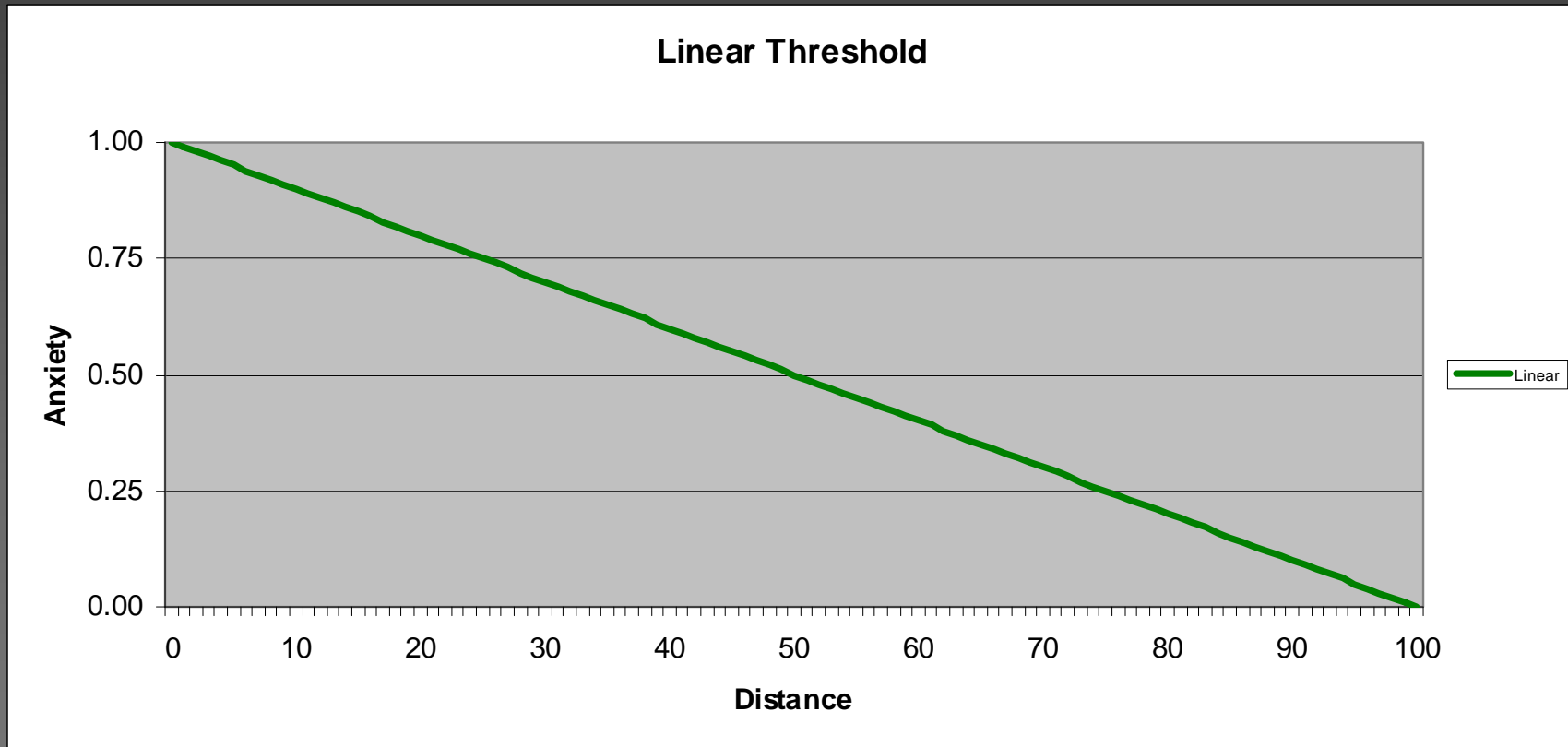


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Linear Formula

$$\text{Anxiety} = (100 - \text{distance}) / 100$$

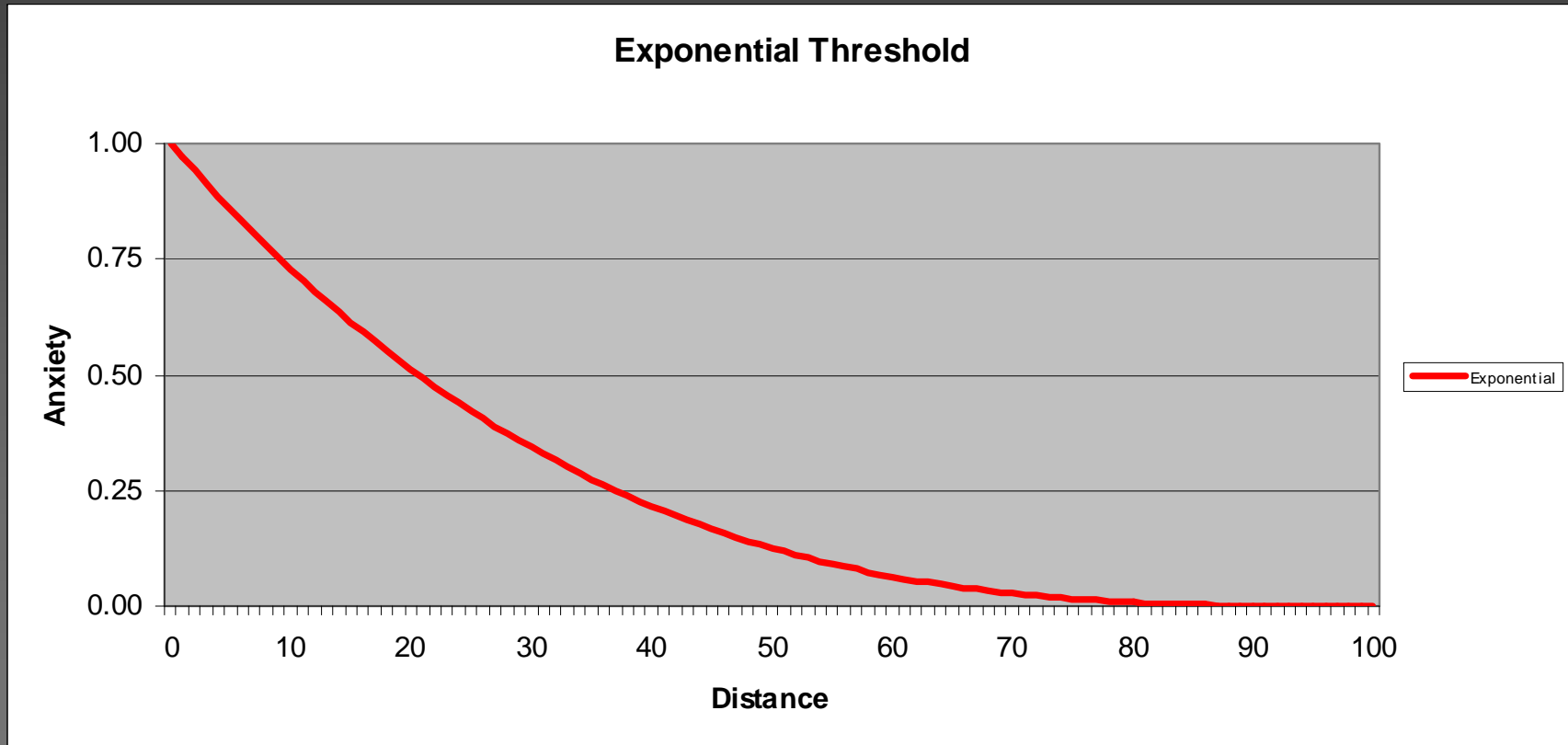


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Exponential Formula

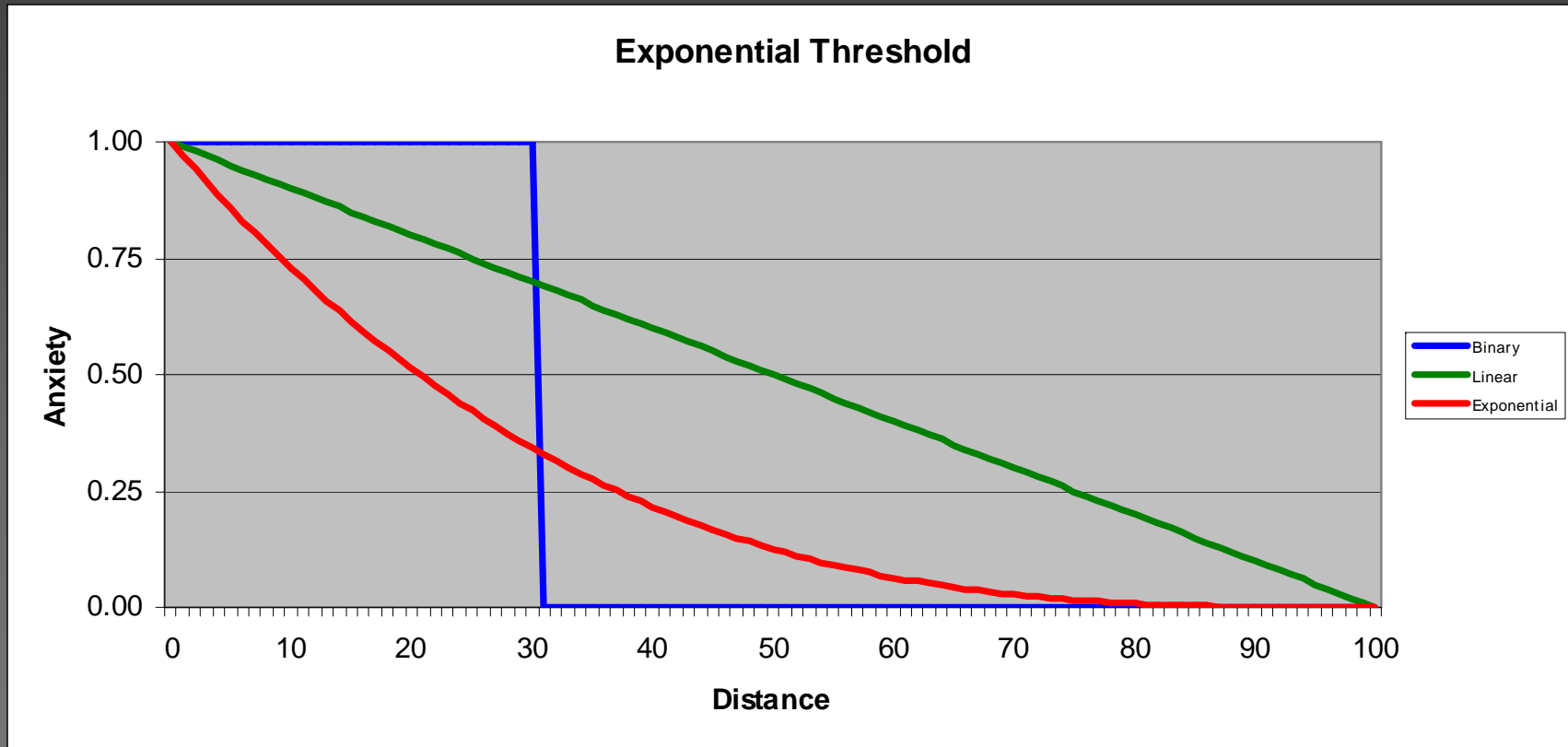
$$\text{Anxiety} = (100 - \text{distance}^3) / (100^3)$$



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Threshold / Linear/ Exponential

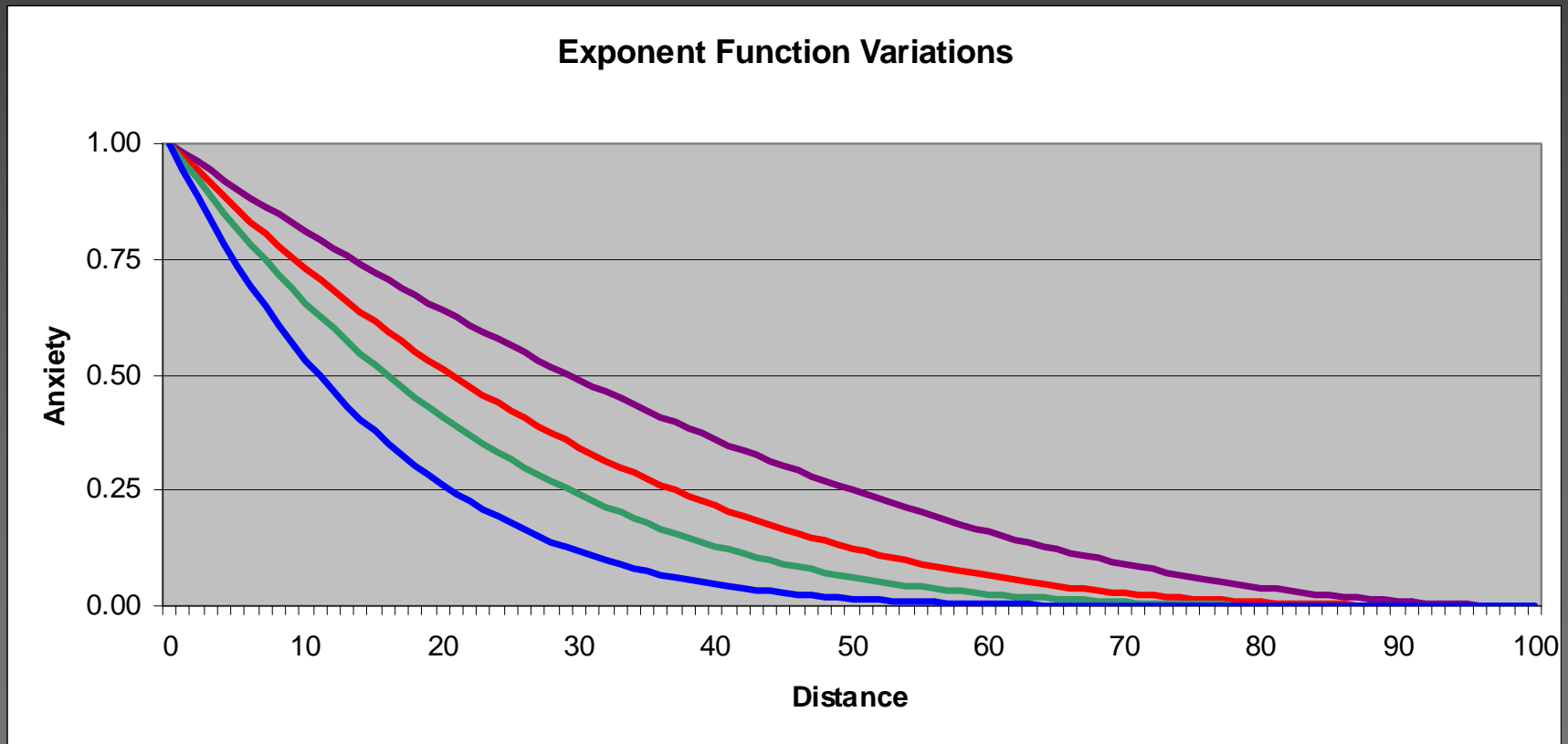


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Changing Exponents

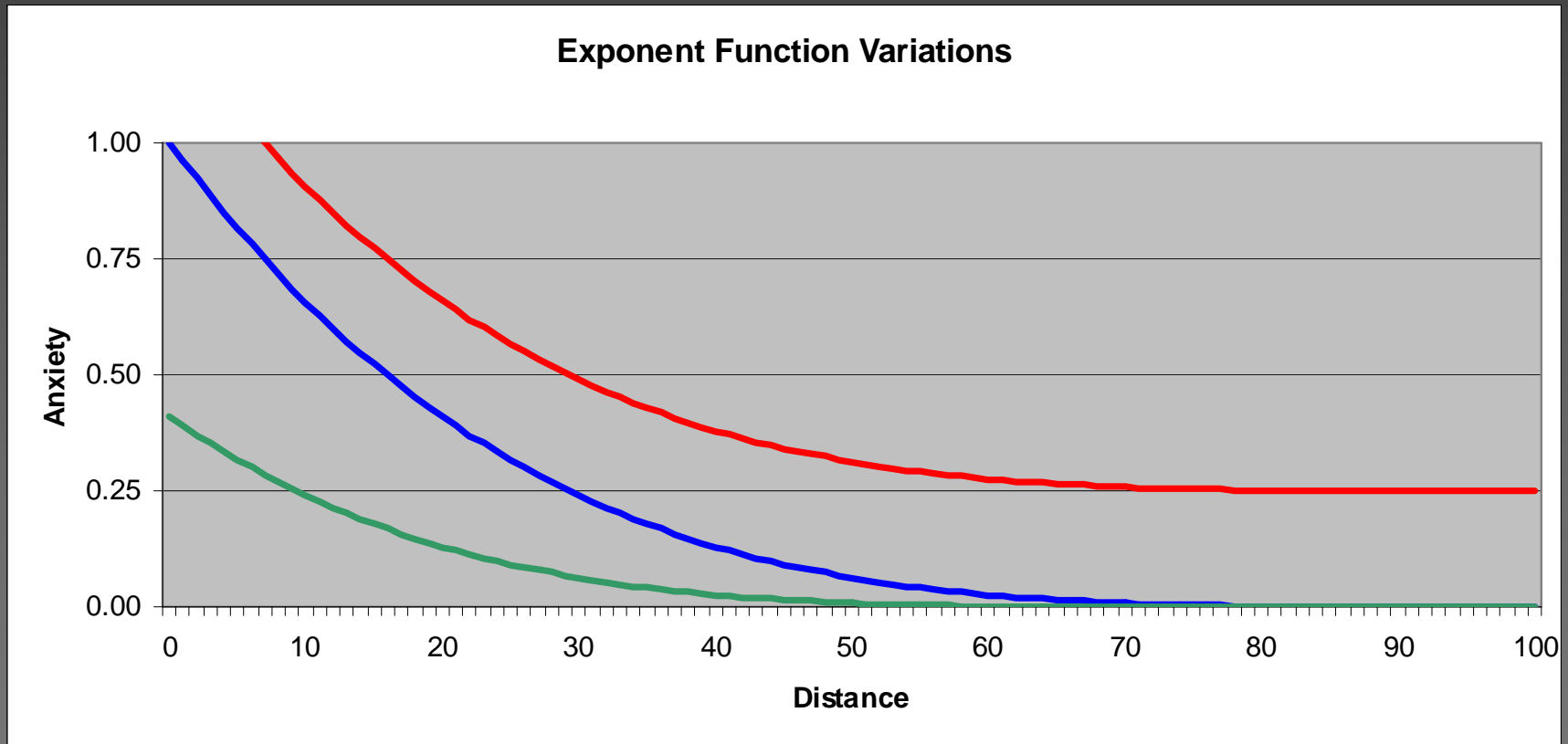
Exponents of 2, 3, 4, 6



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Shifting the Curve



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Logistic Function

$$y = \frac{1}{1 + e^{-x}}$$

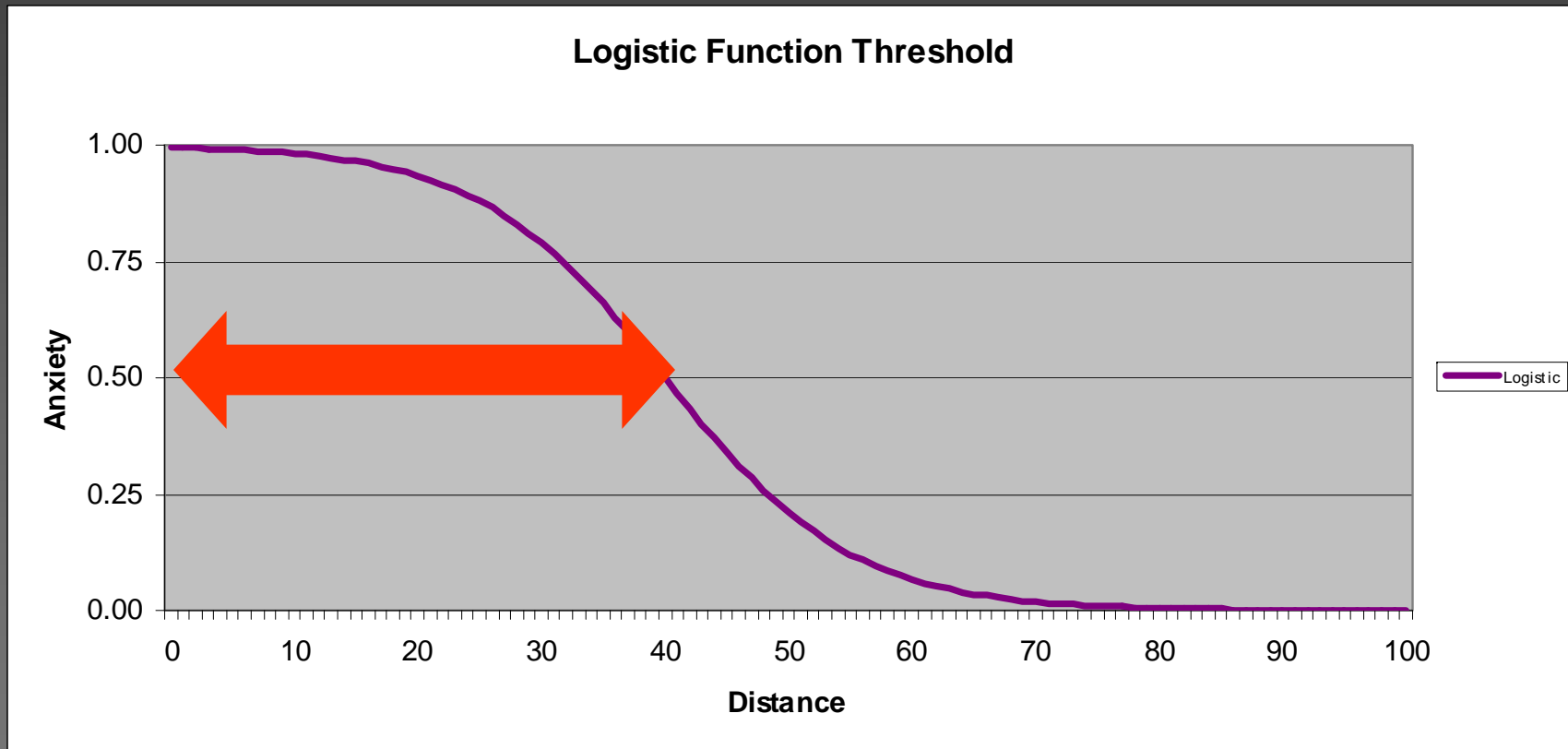


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Logistic Function

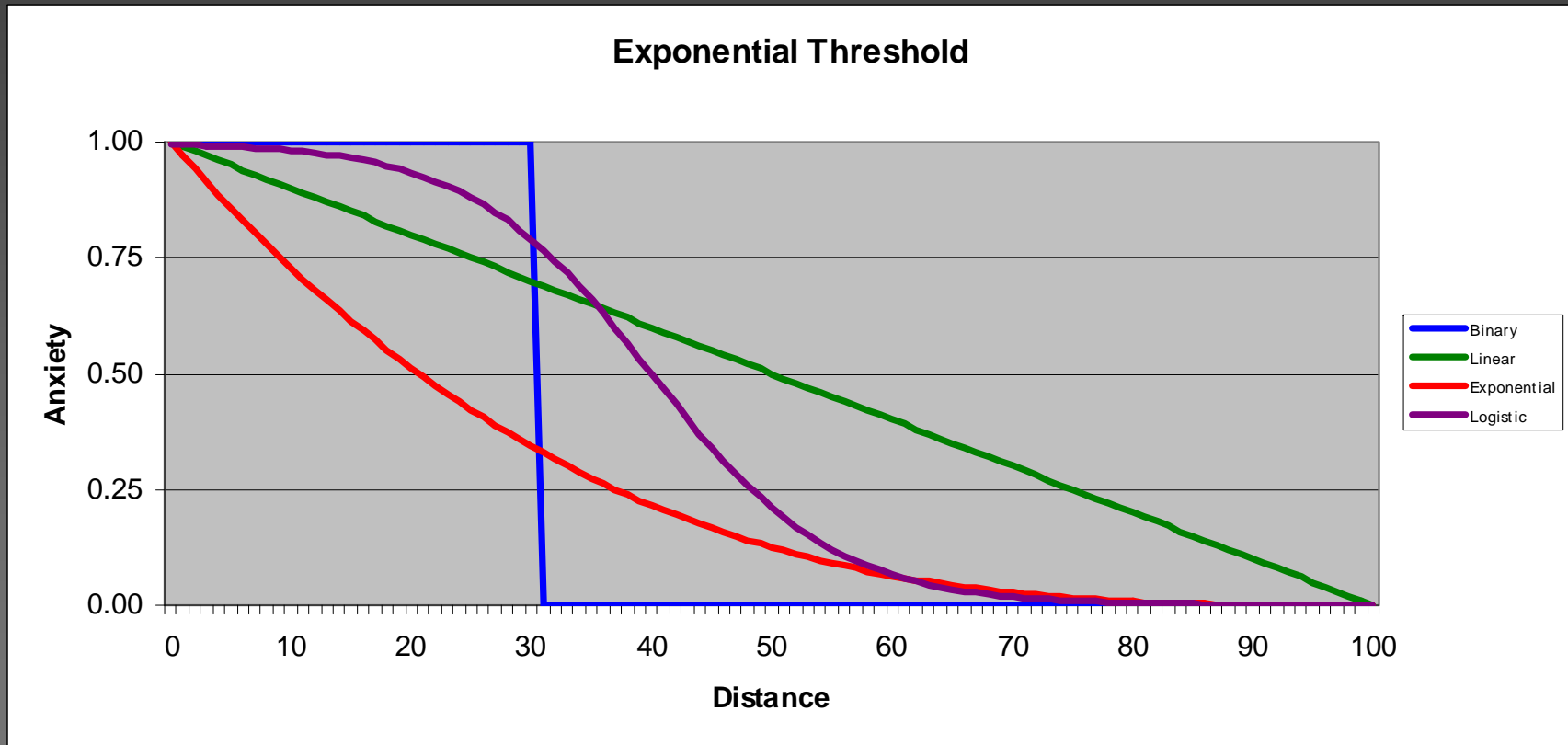
$$\text{Anxiety} = 1 / (1 + (2.718 \times 0.45)^{\text{distance} + 40})$$



“Reducing the world to mathematical equations!”



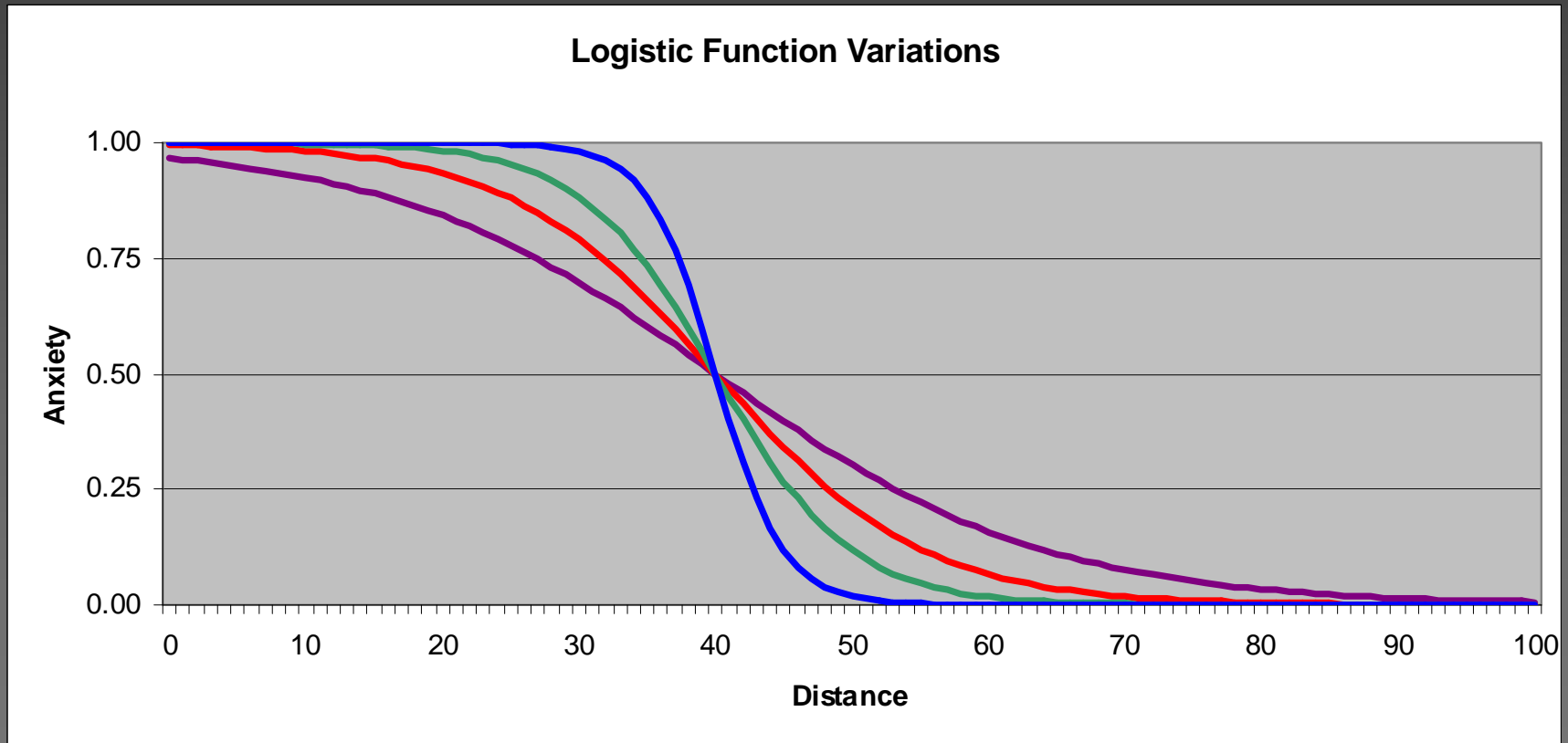
Curve Comparison



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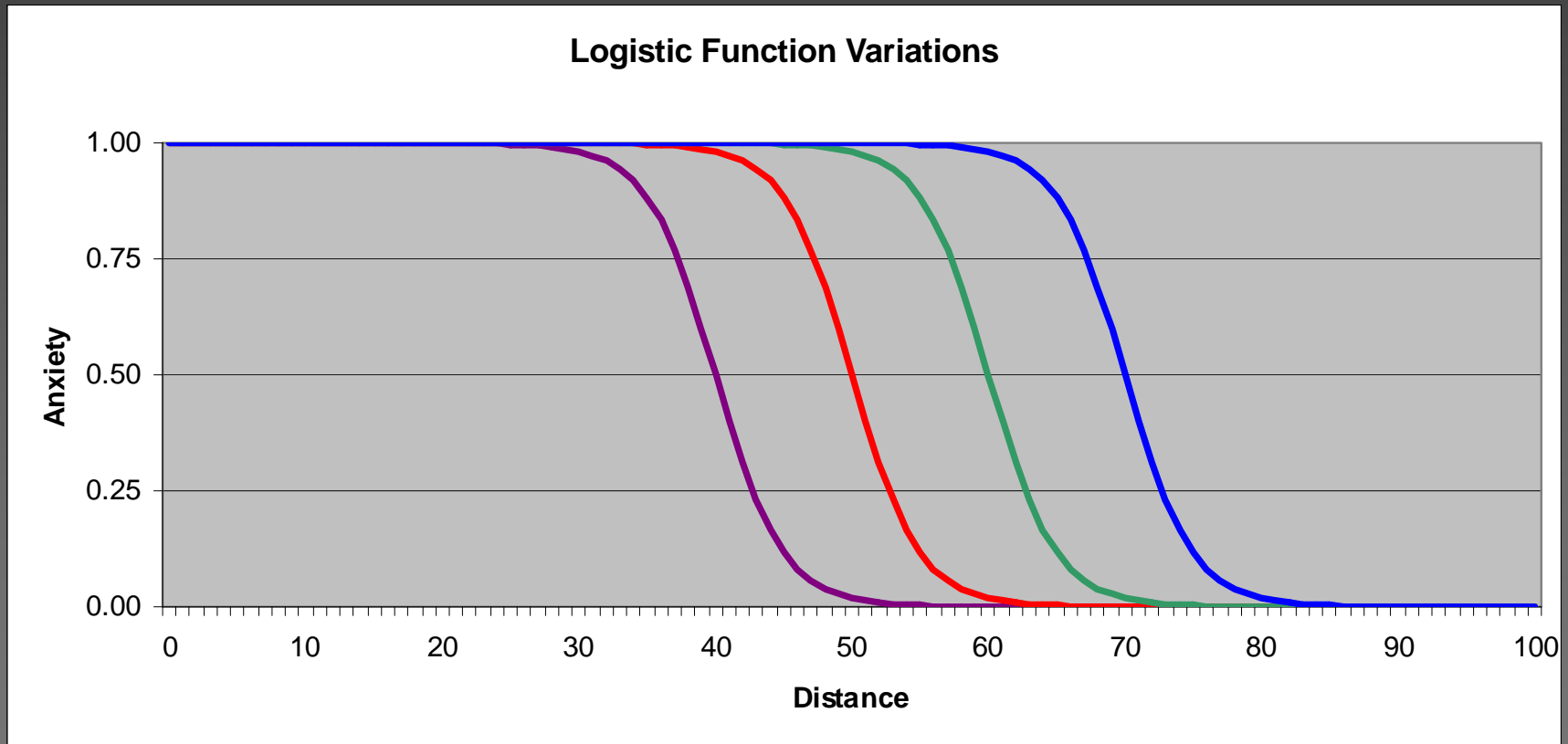
Variations on the Logistic Curve



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Shifting the Logistic Function



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How Can We Express Information?

- Increasing or Decreasing?
- Rates of change
 - Steady or Variable?
 - Inflection Point?
- Amount of change
 - Constrained or Infinite?
 - Asymptotic?



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Know when to walk away...

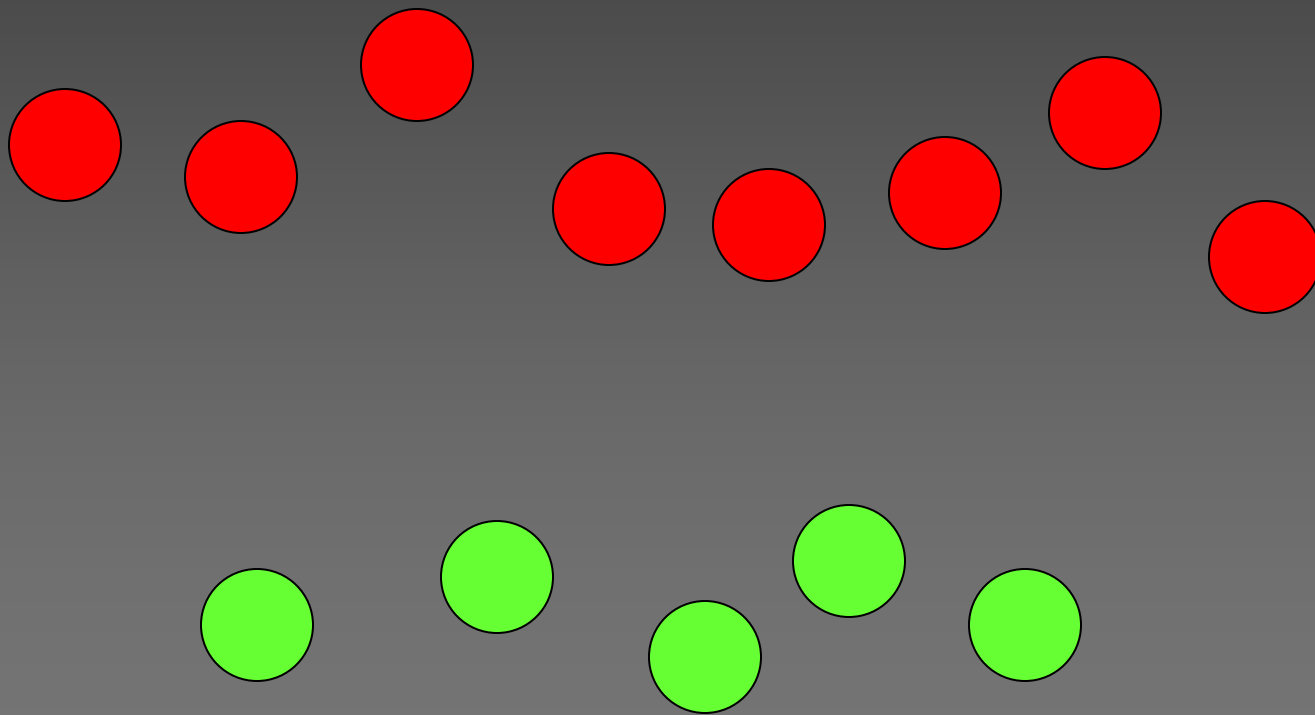
- Design Decision:
 - “Enemies don’t always fight to the death”
- Enemies can sometimes retreat
 - Flat % chance
 - Is random... therefore looks random
 - Not realistic
 - Situational random
 - Based on circumstances
 - Circumstances are flexible and dynamic



“Reducing the world to mathematical equations!”

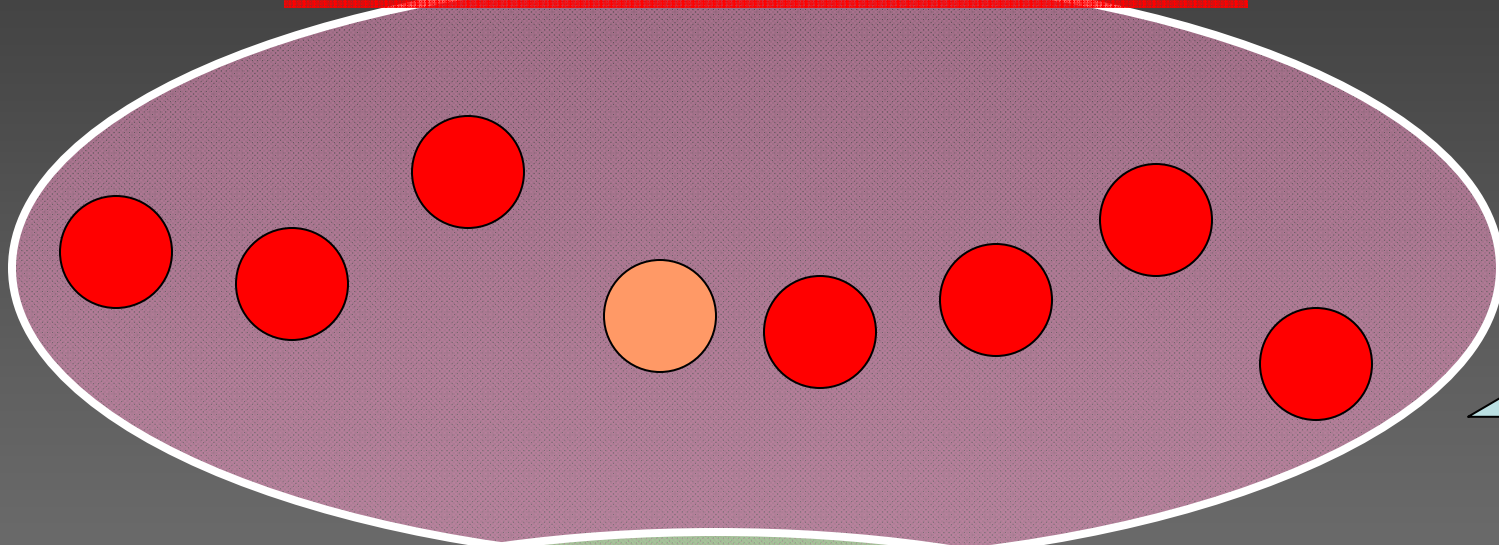


Know when to walk away...



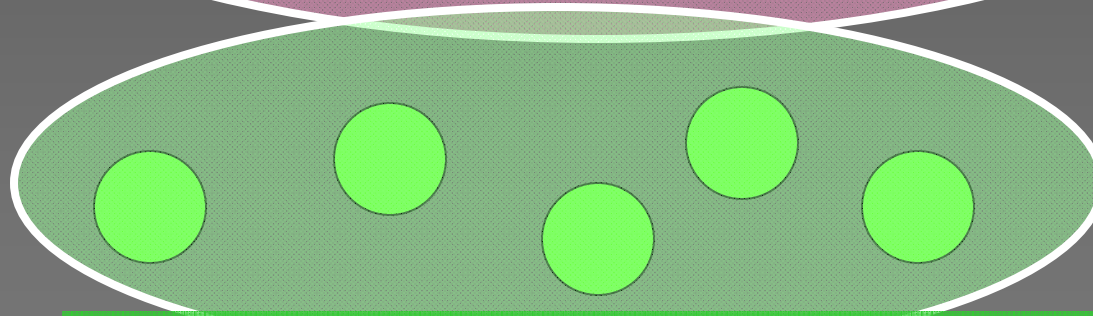
Know when to walk away...

How many on my side are still fighting?



8

1.6



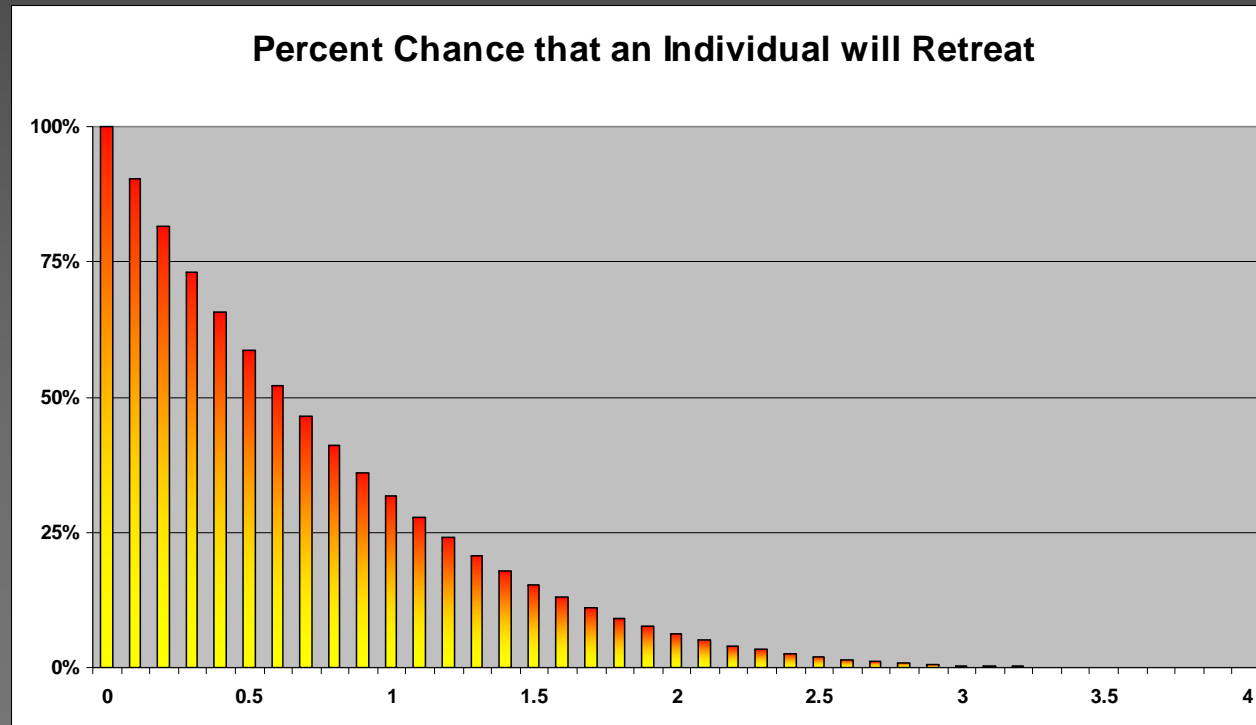
5

How many of my enemies are still fighting?

"Reducing the world to mathematical equations!"

Know when to walk away...

$$\text{PercentChance} = (4 - \text{Ratio})^4 / (4^4)$$



“Reducing the world to mathematical equations!”



Know when to walk away...

$$\text{PercentChance} = (4 - \text{Ratio})^4 / (4^4)$$

$$\text{PercentChance} = (4 - 1.6)^4 / (4^4)$$

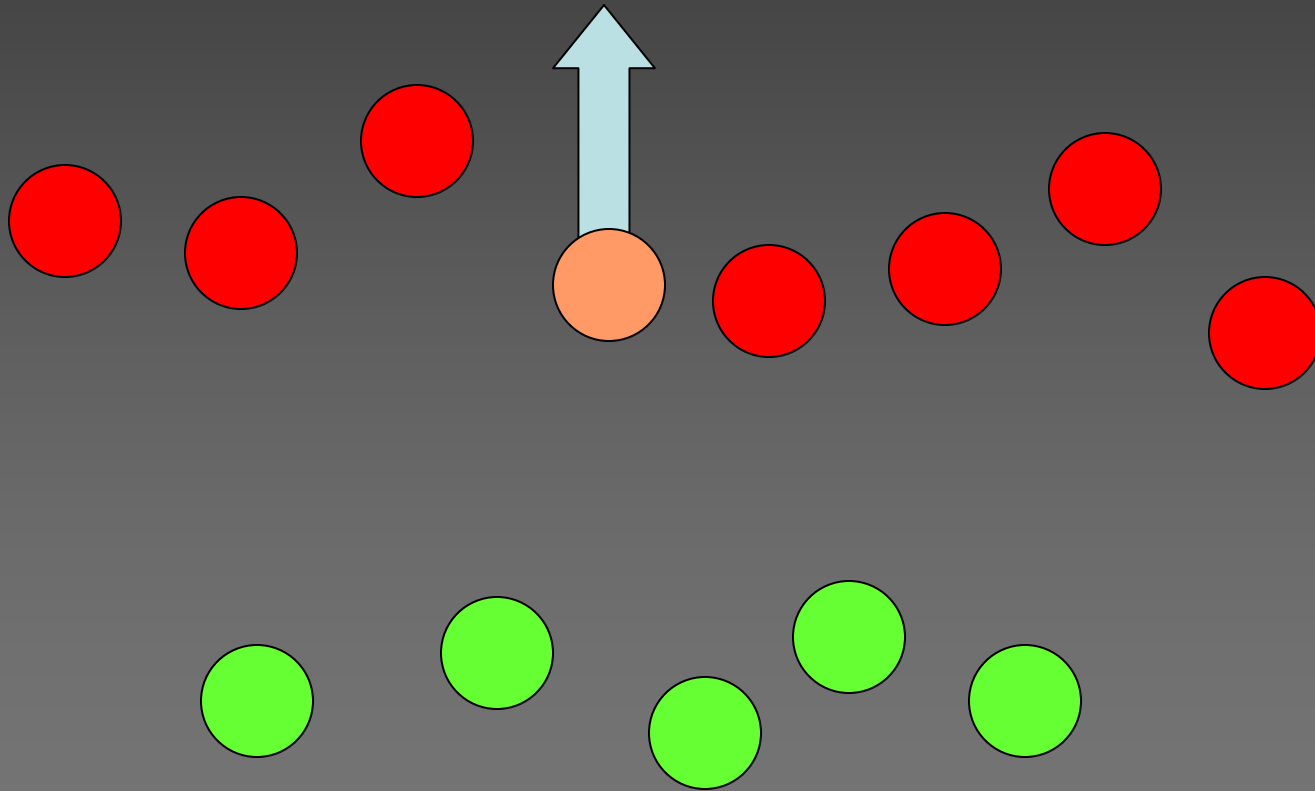
$$\text{PercentChance} = 13\%$$



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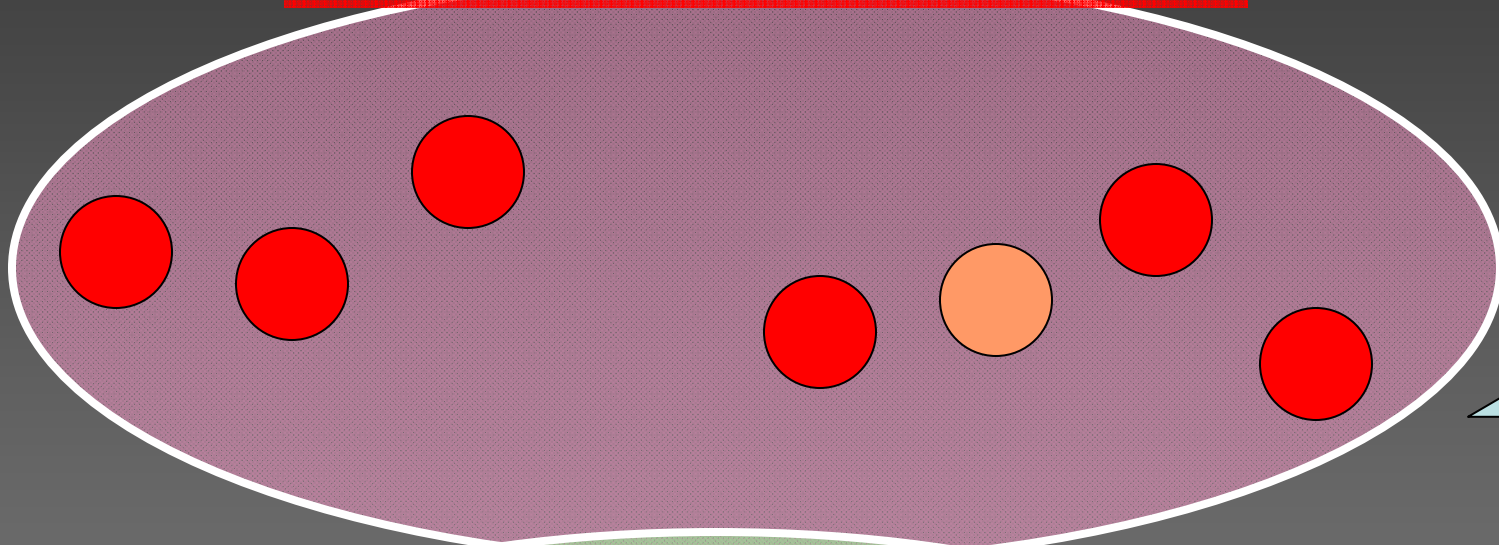


Know when to walk away...



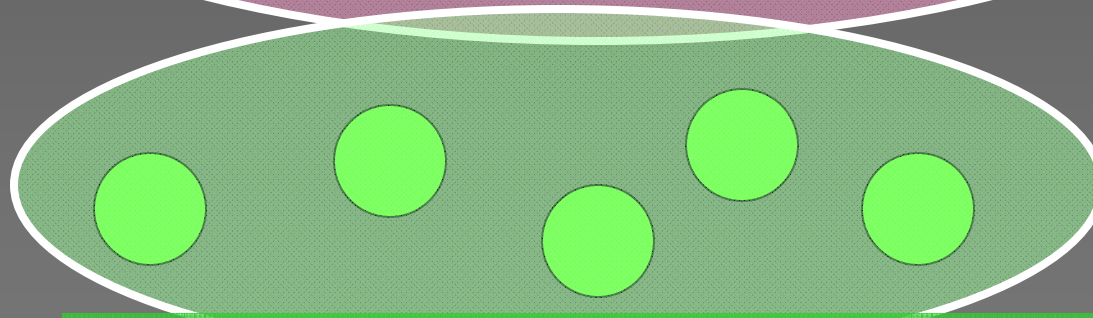
Know when to walk away...

How many on my side are still fighting?



7

1.4



5

How many of my enemies are still fighting?

"Reducing the world to mathematical equations!"

Know when to walk away...

$$\text{PercentChance} = (4 - \text{Ratio})^4 / (4^4)$$

$$\text{PercentChance} = (4 - 1.4)^4 / (4^4)$$

$$\text{PercentChance} = 18\%$$

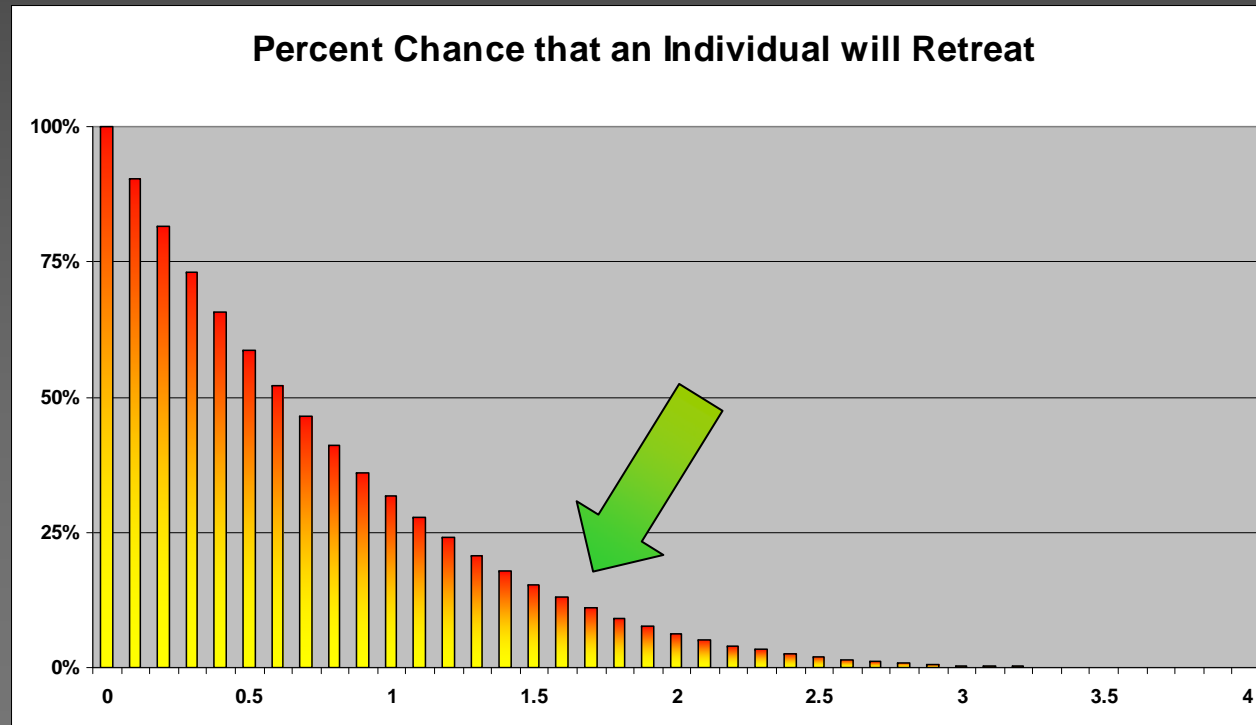


“Reducing the world to mathematical equations!”



Know when to walk away...

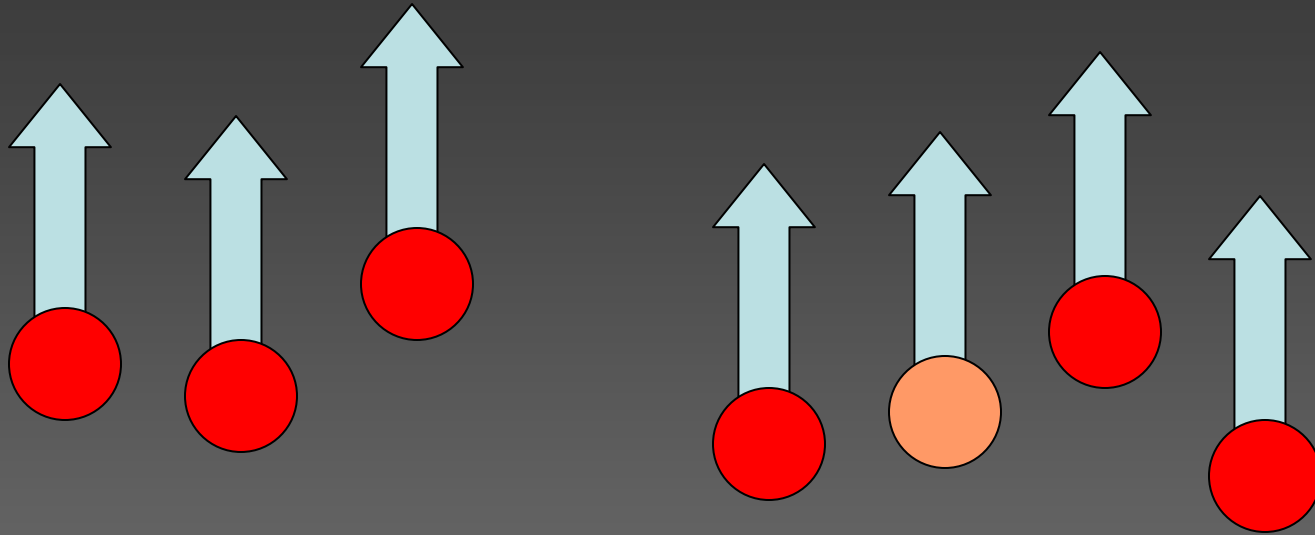
$$\text{PercentChance} = (4 \times \text{Ratio})^4 / (4^4)$$



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Know when to walk away...



How Can We Express Differences?

- Not that information exists (e.g. yes or no) but what that information *says*.
- Identifying more than one factor for input
- Allowing for more than one possible result



“Reducing the world to mathematical equations!”

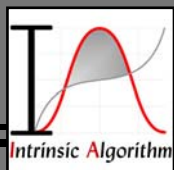


Know when to walk away...

PercentChance =

$$\left((\text{MaxRatio} - \text{Ratio})^k \times \text{MaxPct} \right) / (\text{MaxRatio}^k)$$

	MaxPct	k
In Field	1.00	4
Near Base	0.75	6
In Base	0.50	8

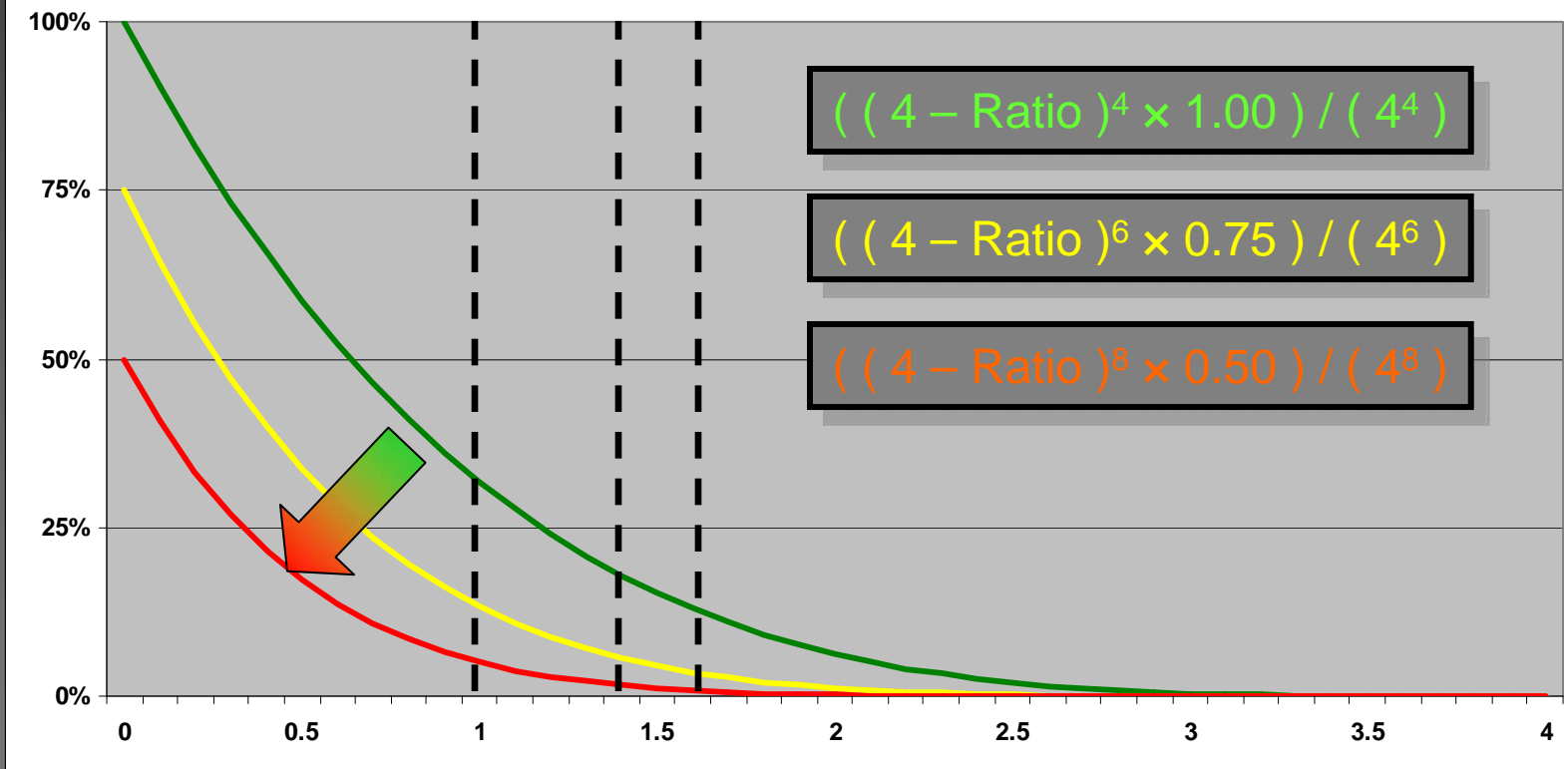


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Know when to walk away...

Percent Chance that an Individual will Retreat



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Know when to walk away...

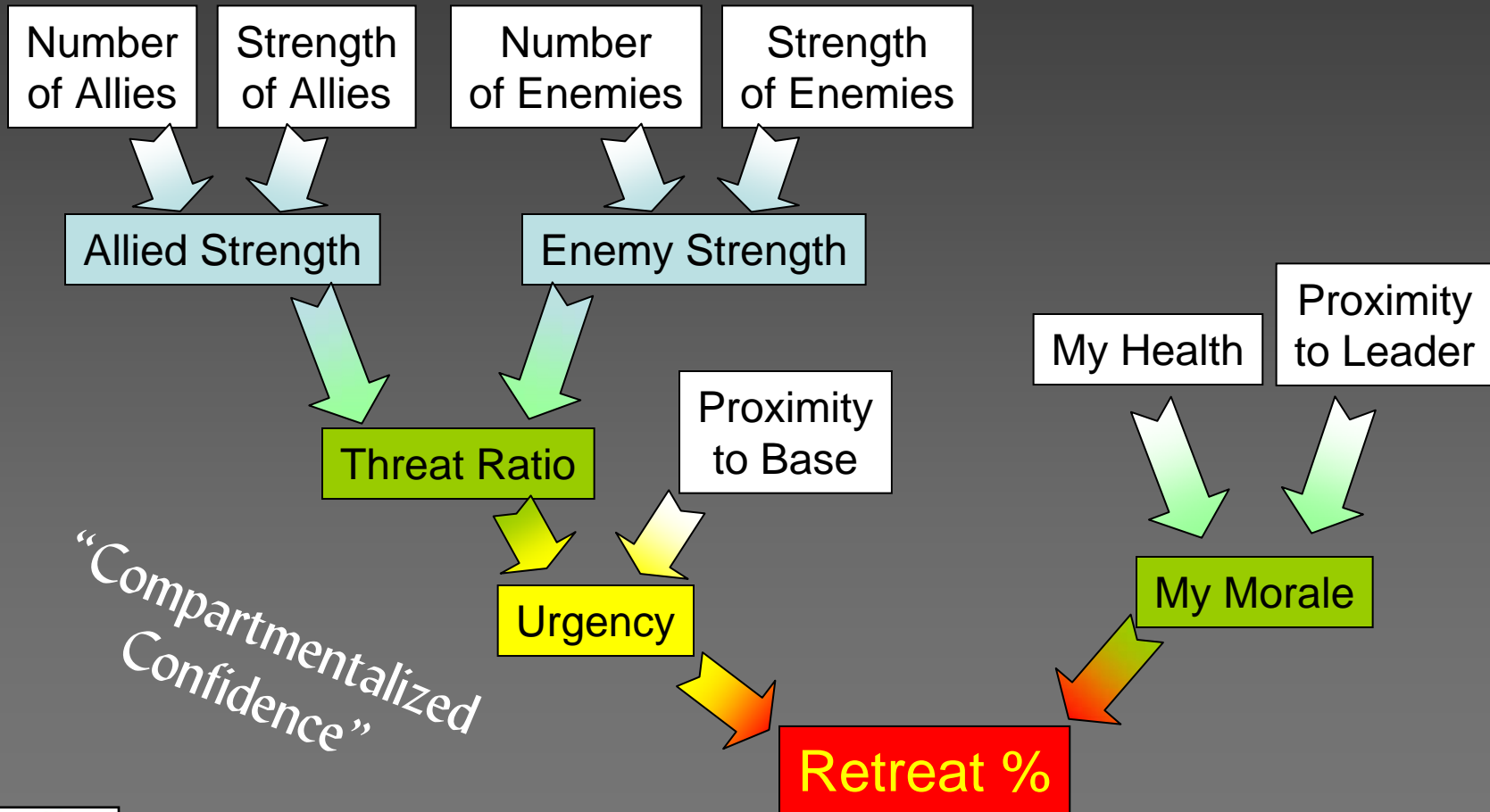
- Factors to Consider
 - Number of allies
 - Number of enemies
 - Proximity to Base
 - Strength of allies
 - Strength of enemies
 - My own health
 - Proximity of my leader



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Know when to walk away...



"Compartmentalized Confidence"

"Reducing the world to mathematical equations!"



How does this look to the players?

- Enemies aren't completely fearless
- They are slightly unpredictable
- They are still reasonable
- Curiosity: "Where is he going?"
- "If we show force, they might break and run."
- "If we back them up, they are more aggressive."
- We have to react to their reactions.



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How Can We Express Differences?

- Not that information exists (e.g. yes or no) but what that information says.
- Identifying more than one factor for input
- Allowing for more than one possible result



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More than “Fight or Flight”

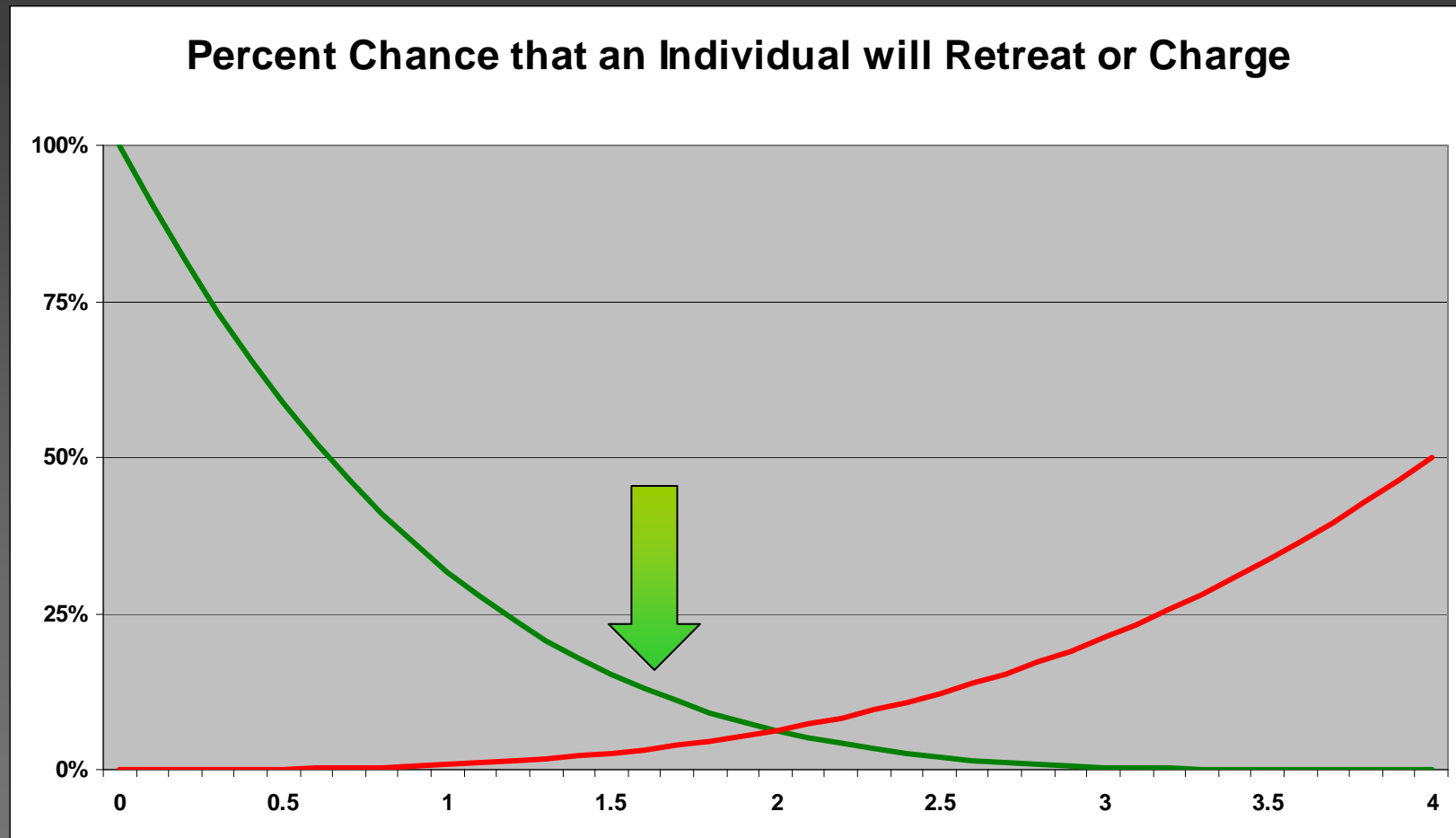
- Fight normally
- Flee
- Charge



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More than “Fight or Flight”



“Reducing the world to mathematical equations!”



More than “Fight or Flight”

- Fight
 - Melee weapon
 - Ranged weapon
 - Special rare weapon
- Advance
 - Press forward
 - Berserker charge
- Retreat
 - Fighting withdrawal
 - Find Cover
 - Organized pull back
 - Flee in abject terror
 - Surrender

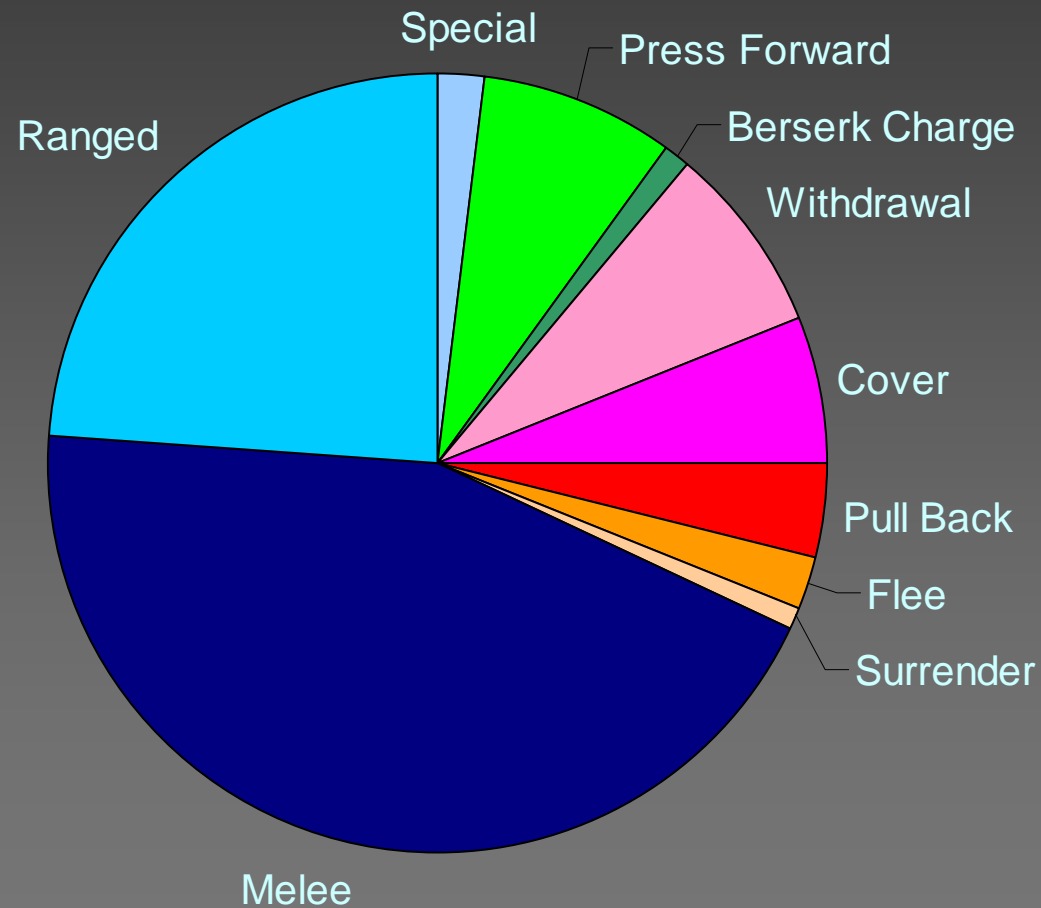
Too many individual curves!!



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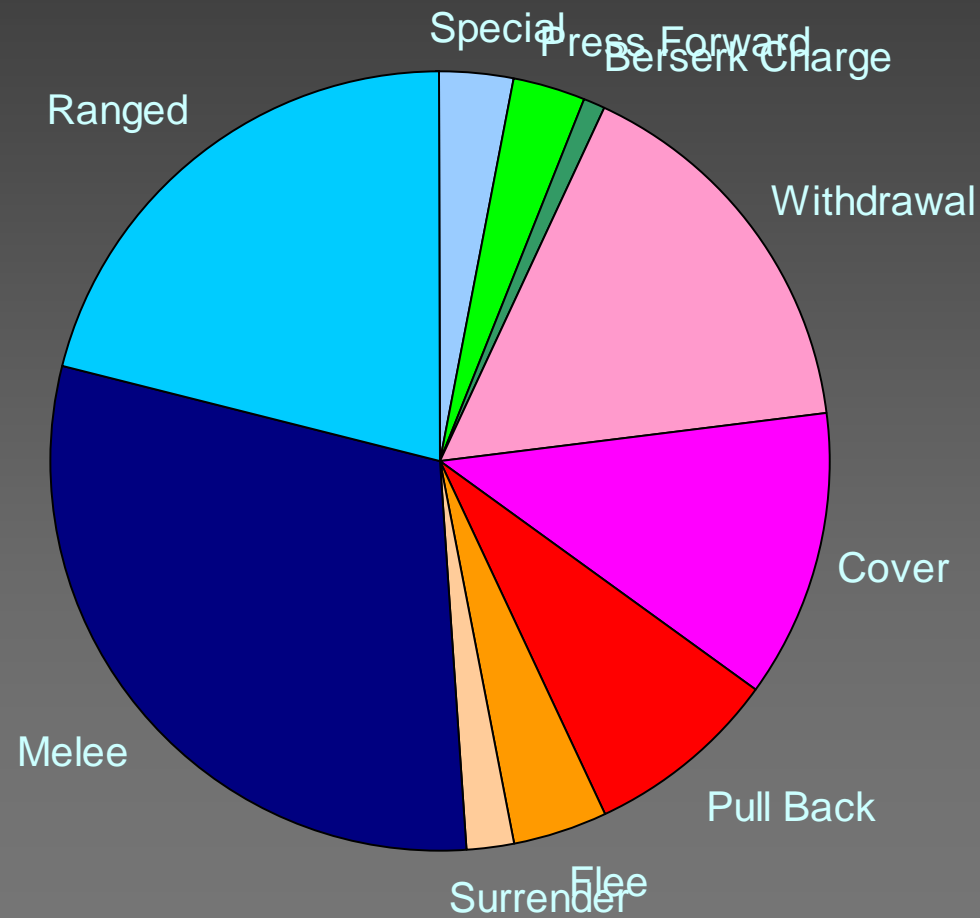
More than “Fight or Flight”



“Reducing the world to mathematical equations!”



More than “Fight or Flight”

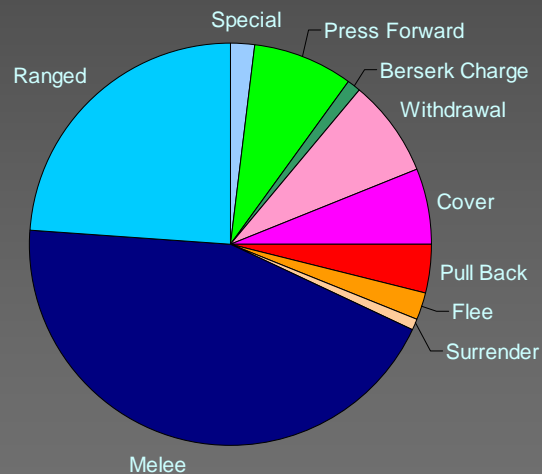


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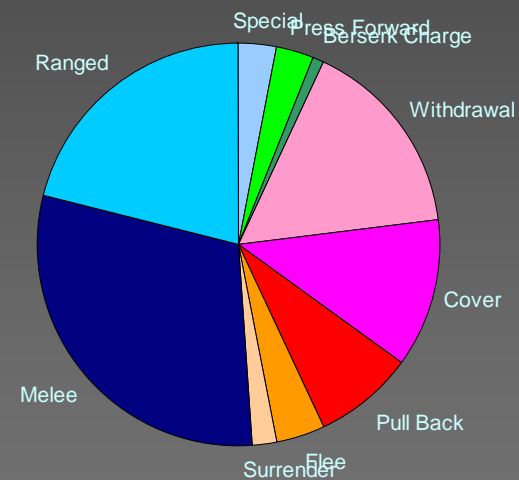


More than “Fight or Flight”

“Normal”



“Wounded”



How do we get to this point?



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Selecting from Multiple Actions

- We can't run one check for each possible action
 - Too cumbersome
 - Each action is mathematically independent
- Structure to place all possible actions in play at the same time.
 - Auto-balancing
 - Expandable
 - Easy to select one action



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Preferences = Differences



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Ordinal Rankings

1



4



2



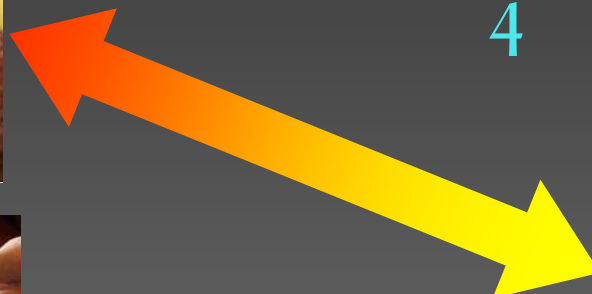
5



3



6



Measuring Information

- Identifying differences
 - Is ordinal enough?
(i.e. $a < b < c$)
 - If more, then how much more?
(e.g. $a = 2 \times b$)
- Normalization (e.g. 0..1)



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Normalizing Ratings

1.0 = “the best possible”

0.0 = “the worst possible”

0.1



0.3



0.5



0.6



0.75



0.9



0

Normalized Satisfaction

1



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You Can't Always Get What You Want

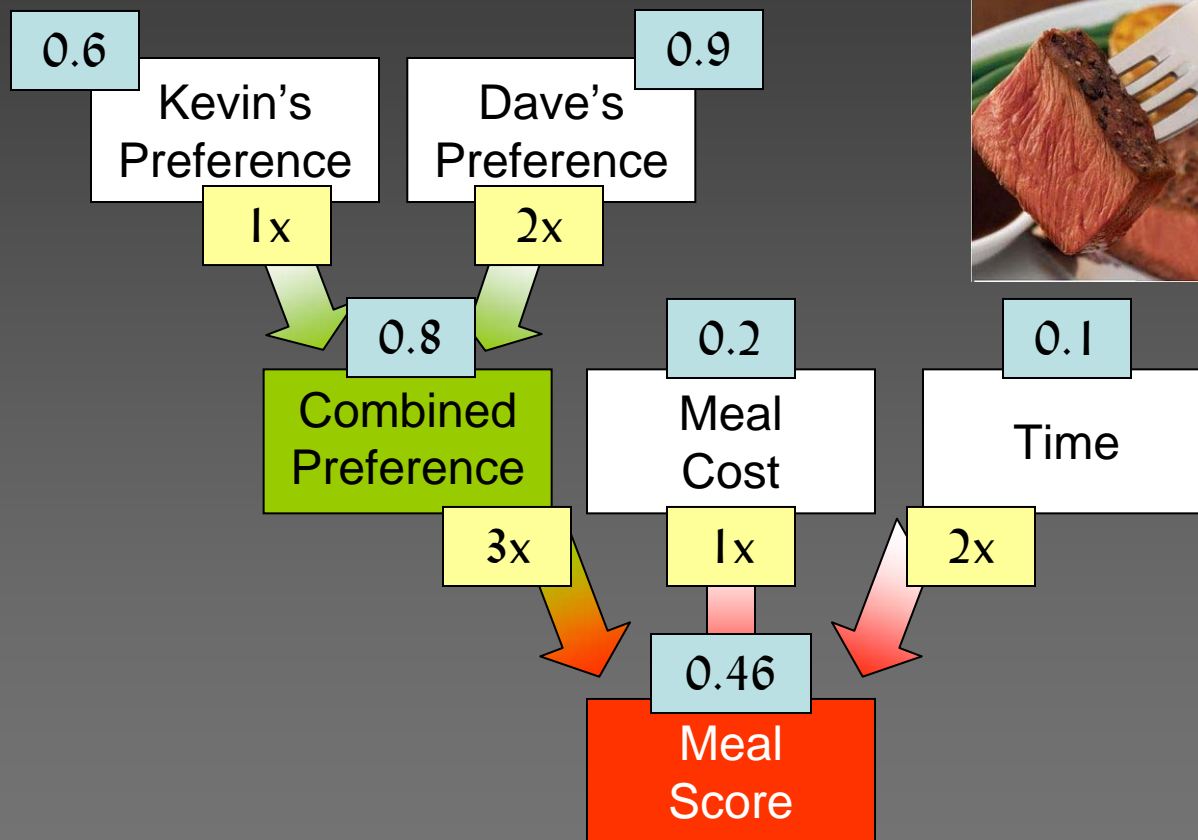
- Multiple Preferences
 - Mine
 - Kevin's
- Cost (Is Kevin paying?)
- Time (Do we still need to finish our slides?)



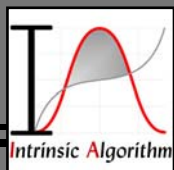
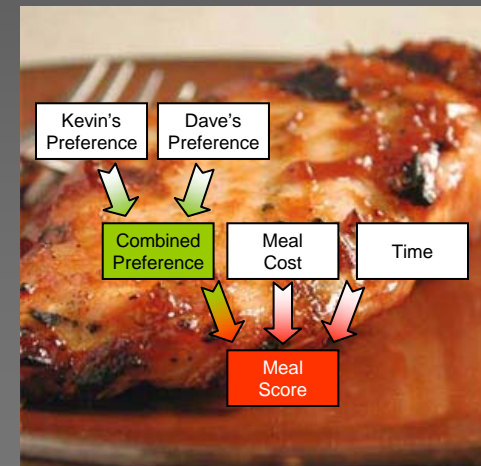
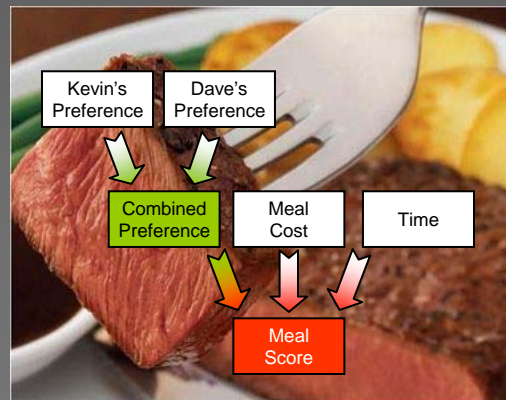
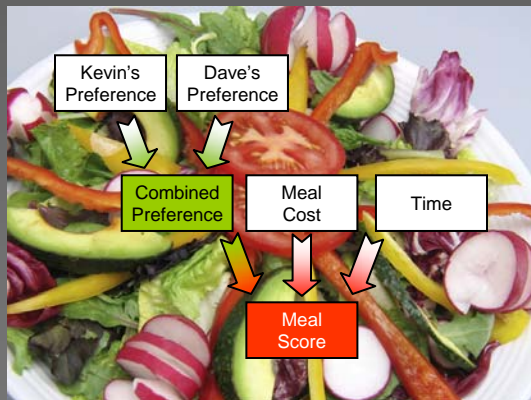
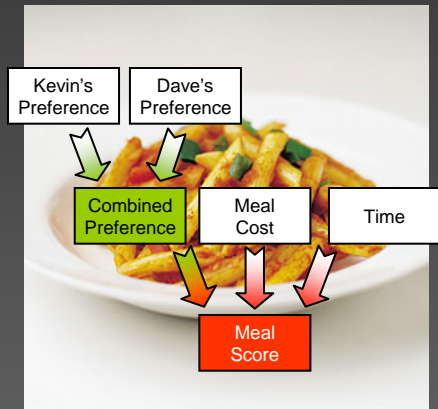
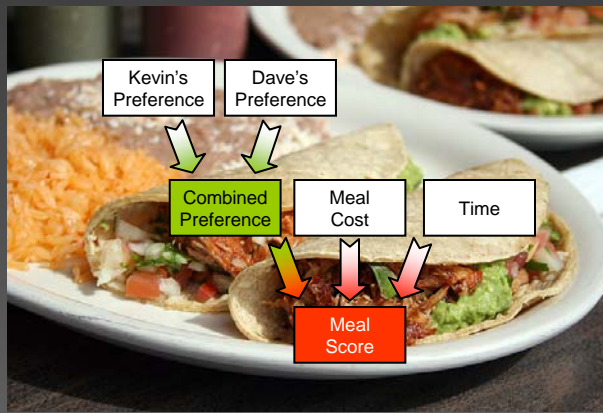
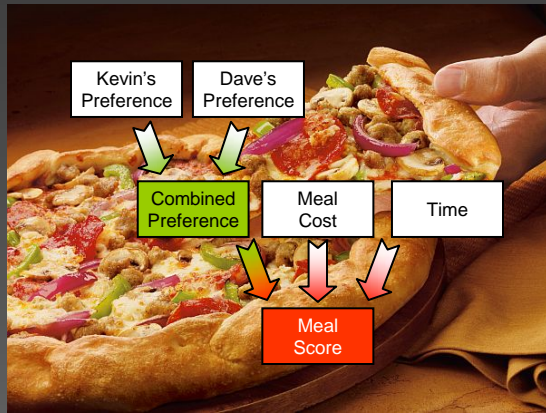
“Reducing the world to mathematical equations!”



You Can't Always Get What You Want



You Can't Always Get What You Want



“Reducing the world to mathematical equations!”



You Can't Always Get What You Want

Meal	Kevin	Dave	Pref.	Cost	Time	Score
Steak	0.6	0.9	0.80	0.2	0.1	0.47
Pizza	0.5	0.7	0.63	0.6	0.8	0.68
Chicken	0.7	0.6	0.63	0.4	0.3	0.48
Tacos	0.2	0.4	0.33	0.5	0.4	0.38
Salad	0.6	0.3	0.40	0.7	0.9	0.62
Pasta	0.8	0.1	0.33	0.8	0.8	0.57

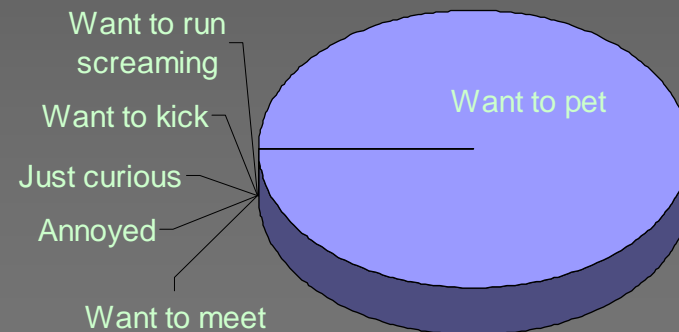


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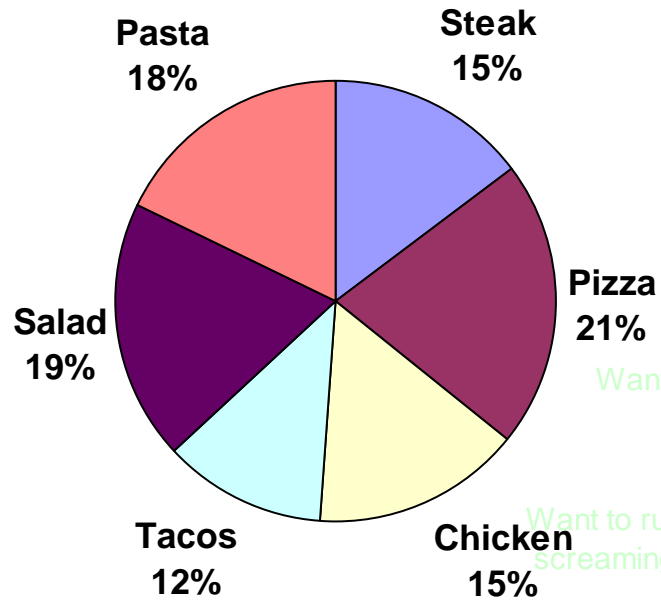
Selecting a Result

- Select Top Score
- Random from top n choices
 - E.g. “Pick evenly from top 3”
- Weighted random
 - All possible
 - Top n



Selecting a Result

What's for Dinner?



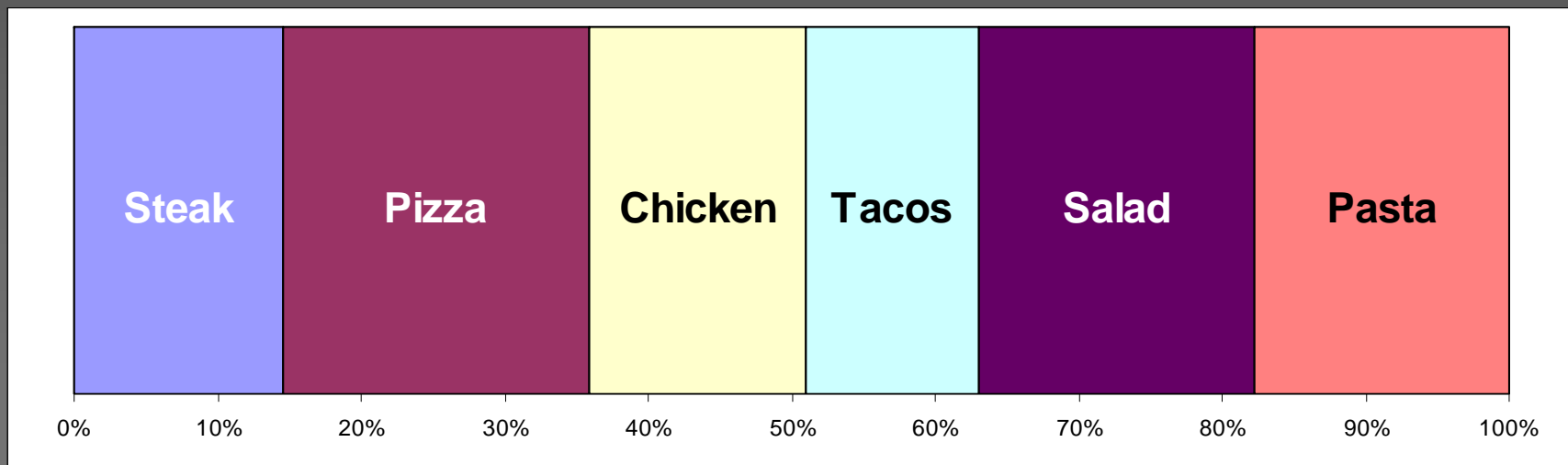
“Reducing the world to mathematical equations!”



Weighted Random Selection

Generate a random number...

And let the bouncing ball choose.



“Reducing the world to mathematical equations!”



So what have we learned?

- People are different.
 - Different reactions to the same stimulus
 - Not random but reasonable
- Beyond just checking for information
 - What does that information mean to the decider?
 - How do different inputs relate to each other?
- Allow multiple reactions
 - Not just “the best” (Don’t *always* pet nice doggie.)
 - Base the possibility of a reaction on its merit



“Reducing the world to mathematical equations!”



Dave Mark

Intrinsic Algorithm LLC

Intrinsic Algorithm

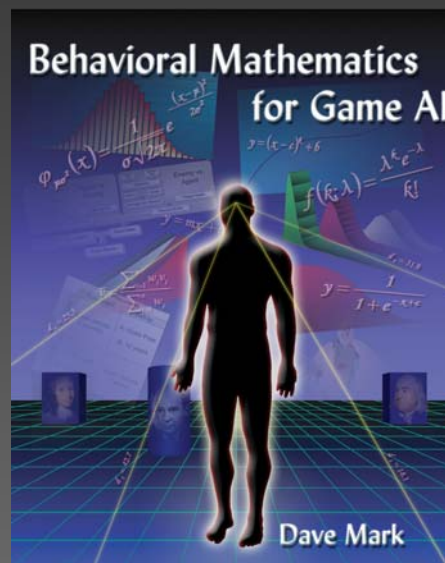


What AI sees when it looks in the mirror...

Dave@IntrinsicAlgorithm.com

www.IntrinsicAlgorithm.com

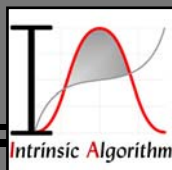
(402) 208-7054



IADaveMark

on:

Yahoo – AIM - Twitter



“Reducing the world to mathematical equations!”



Kevin Dill



- Senior AI Engineer, R* New England
- Lecturer, Boston University
- Section Editor, AI Game Programming Wisdom 4



“Reducing the world to mathematical equations!”



This Is A Tiger

[Tiger.mov](#)



“Reducing the world to mathematical equations!”



This Is A Tiger

- Constantly moving, constantly attending
- No looping or repetitive animations
- No straight lines or crisp turns
- Believable, organic, grounded in and reactive to the world around him
- *We won't be truly photorealistic until we achieve this*



“Reducing the world to mathematical equations!”



The Big Picture

- Build strong cross-disciplinary teams
 - AI & animation
 - AI & dialog writers
 - AI & sound
 - Designers, QA, etc.
- Build capabilities from game to game
 - e.g. Natural Motion
- Retain (and develop) your core talent!!



“Reducing the world to mathematical equations!”



Be An AI Artist

- Become an observer
 - How people move
 - How they interact
 - How they gesture
 - What they say
- Different situations
 - Halls & doorways
 - The mall
 - Parties & social groups
 - The boss's office
- Get lots of eyes on it
 - Your wife & friends
 - Your players
 - The animators
 - QA
- ***Crave criticism!!***



“Reducing the world to mathematical equations!”



Behavioral Building Blocks

- Get core behaviors to work, build up
- Think about our tiger
 - Breathing
 - Fidgets: yawning, stretching, twitching, etc.
 - Attention
- Build those animation performances
- Build idles, movement behaviors
- Build play, eat, fight, sleep, work, ...



“Reducing the world to mathematical equations!”



Believable, Organic

- Break the animation loop
- Multiple asynchronous animations
 - Separate out breathing, tail, etc.
 - Attention
- Random variance
 - Speed
 - Blend weights
 - Bone positions
 - Wiggle (Perlin noise)
- Blend procedural techniques & animation



“Reducing the world to mathematical equations!”



Grounded & Reactive

- Types of targets:
 - Neutral
 - Random
 - Object / entity
 - Event
- Types of attention
 - Ear twitch / cock head
 - Headlook
 - Behavior change
- Library of reactions
- What to do next?



“Reducing the world to mathematical equations!”



No Straight Lines

- Path planner is just a general guide
- Do good smoothing, add a little wander
 - Use your terrain abstraction
- Or, flow fields to guide animation selection
- Support multiple locomotion modes
 - Walk, run, crawl, jump, climb, swim
 - Smooth, natural transitions
- Stop anywhere. Reach from anywhere.



“Reducing the world to mathematical equations!”



Dave Mark

Dave@IntrinsicAlgorithm.com

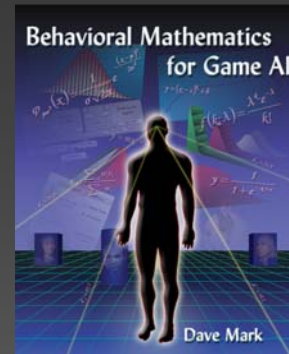
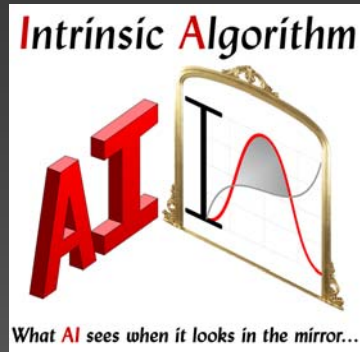
www.IntrinsicAlgorithm.com

(402) 208-7054

IADaveMark

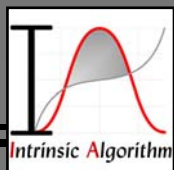
on:

Yahoo – AIM - Twitter



Kevin Dill

kdill4@gmail.com



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