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MEASURING THE EFFECTS OF ALTRUISM ON GAME AGENT SURVIVABILITY AND
PLAYER PERCEPTIONS

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Abstract

Modeling realistic altruism for nonplayer characters (NPCs) is an interesting problem with substantive potential benefits to game creators and players, in the form of more believable game characters and immersive games. As an attempt at showing the potential for altruistic behavior in non-player characters, this paper first describes an experiment to investigate how those behaviors will change the behavior of game agents being acted upon by other well-established behavioral algorithms. A second experiment was conducted to investigate how humans would interpret altruistic behavior in game agents. In particular, the experiment focused on whether human observers would attribute emotional characteristics and motivations to altruistic game agents.

NPCs in a predator/prey dynamic were observed in a simulation, with the prey characters exhibiting autonomous flocking behavior and the predator characters hunting the prey. The experimental groups also exhibited altruistic distracting behavior, and their behavior was compared to a control group without this behavior. Prey whose members engage in altruistic behavior lived longer and had more descendants on average.

In a second experiment, human-subject participants viewed a video recorded from this simulation, either with or without altruistic behavior. They were given a pair of survey instruments to collect both qualitative and quantitative data on their perceptions of the NPCs' behaviors and motivations. The quantitative data showed a clear belief that participants believed that NPCs in the experimental video cared for members of their social group and were willing to sacrifice themselves. Results from the qualitative data were less clear, but showed several interesting results. Although participants used no more, and in some cases less, positive emotional words to describe the experimental video, they used significantly more negative

emotional words to describe the control video.

Dedication

To my wife, Becca, with all my love.

Acknowledgments

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Chapter 1: Introduction

Modeling realistic altruism for nonplayer characters (NPCs) is an interesting problem with substantive potential benefits to game creators and players, in the form of more believable game characters and immersive games. As an attempt at showing the potential for altruistic behavior in non-player characters, this paper first describes an experiment to investigate how those behaviors will change the behavior of game agents being acted upon by other well-established behavioral algorithms. A second experiment was conducted to investigate how humans would interpret altruistic behavior in game agents. In particular, the experiment focused on whether human observers would attribute emotional characteristics and motivations to altruistic game agents.

The generation of stories and scenarios in open-world computer games is typically done by game designers through a laborious scripting process. The process is expensive, time-consuming, error-prone, and can often result in unrealistic results that break games' immersiveness. NPC's emotions are typically communicated through text or spoken dialogue. Their emotional displays can oscillate wildly as they talk about different, unrelated topics, as dictated by their scripting. These richly-rendered, expansive worlds are typically populated by shallow, non-believable game NPCs.

This paper presumes that perceptions of NPCs' emotions can be effectively influenced through NPCs actions. Believable story generation through dynamic text and voice generation is an interesting research problem, but one quite different from the scope described herein. This paper proposes that game agents should be to demonstrate behavior game players will interpret has emotionally motivate based upon their interactions with the player and with other NPCs.

Altruism has been shown to be an evolutionary trait [Hamilton, 1963]. However, in

humans altruistic behavior is often associated with and attributed to emotional reactions by outside observers. [Sober and Wilson, 1998] One of the goals of this research project was to determine whether game players would attribute altruistic behavior in NPCs to emotional motivations. The other was to determine how adding this behavior to games would change the dynamics of the game world. Simulations with well-established artificial intelligence algorithms that simulate biological flocking processes were run with and without altruistic responses to compare their performance. Two types of NPCs engaged in a predator/prey dynamic and various metrics on their behavior and survivability were recorded.

1.1 Hypotheses

1. Adding self-sacrificial, altruistic behaviors to NPCs exhibiting flocking behaviors will impact the behavior of the flock by affecting variables such as population count, mean age, and ratio of prey targeted to prey eaten.
2. Humans viewing the self-sacrificial behavior will view it as altruism and will attribute emotional motivations to this behavior.

Chapter 2: Related Work

2.1 Game Emotion Scripting

NPC emotion is typically communicated through text or prerecorded voice acting triggered by static scripts created by game designers. Some games communicate emotion through character and facial acting, but such animation systems are beyond the scope of this paper. The process of developing those scripts is time-consuming and, like all coding, error-prone. These errors can be game-breaking and costly to correct; poor-selling games may never be patched.

Additionally, the boundaries around NPC emotion are typically quite stark. A NPC may be extremely distraught one moment and upbeat the next if so directed by its scripting. The NPC itself has no concept of its emotional state from one behavioral state to the next.

In the Elder Scrolls games, players speak to NPCs by selecting topics to navigate a dialogue tree. The text and pre-recorded, voice acted lines NPCs respond with are the only way emotion is conveyed in these games. The differing emotional tone in NPCs' responses to different topics are not modulated by their emotional state, often creating unrealistic responses that make the characters seem emotionally unrealistic in a way that can disrupt the immersiveness of the experience.

In the Halo franchise, some lower-ranked, weaker enemies are assigned to more powerful squad leaders. If the leader is defeated, the weaker enemies will panic and momentarily scatter. While this is an interesting use of emotion-based behavior, none of the enemies appear to be independently choosing to implement this behavior. The scenario plays out exactly the same, every time, without variation. Additionally, the weaker enemies quickly revert to the uncoordinated attack behavior implemented by otherwise identical enemies not assigned to a

squad leader.

2.2 Budgets/Types of Game Funded

Open world games are nonlinear games in which the player has significant freedom of mobility and is to some degree in charge of the order in which story events will occur. These games typically feature a large world with a large cast of characters. This requires a significant amount of resource creation, which in turn requires a significant investment of time and money. Smaller companies are less likely to be capable of this investment. This limits the number of game development studios who can create these types of games this scope. Automated content creation would enable more companies to make more types of games.

2.3 Crowd Behavior

A number of researchers have studied the feasibility of using the swarming rules developed by Reynolds to integrate emergent crowd behavior into games. [Chiang, 1996; Reynolds, 2006; von Mammen, 2008] However, none of these models explore human perceptions of these behaviors and whether human observers attribute emotional attributes to these agents. They do show the potential for using crowd-based rules to develop more complex and believable game agents. This paper details an implementation of swarming with additional behaviors added to the simulation.

2.4 Emotional Contagion

Several researchers have studied the effects of emotion contagion in simulating crowd behaviors. [Dimas, 2011, Tsai, 2012, Xiang, 2012] Tsai et al stressed the importance of emotional

contagion in producing more realistic simulations for use in what they dubbed “high-risk, high-impact” situations such as military training and virtual psychotherapy. [Tsai, 2012] Dimas et al tested a system whereby the emotional state of AI characters were impacted by the state and emotions of other characters and found that game players preferred this to a system without emotional modeling. [Dimas, 2011] Xiang et al used a heat conduction model to dynamically transmit emotional states between agents in a spectator crowd situation. [Xiang, 2012]

This project studied emotion-based behavior in a group dynamic, but did not consider how emotion might be transmitted between agents. Chapter 8.4 details a future project that uses techniques similar to that proposed by Dimas. While a similar technique was considered here, it was removed to keep the scope of the project from growing too large.

2.5 Emotional Intelligence

Arrables et al proposed emotion as a part of human behaviors (also including “...planning, learning, user modeling, set shifting, and attention modeling...”) needed to simulate consciousness in machines. They discussed a modified Turing test to “assess the believability of video game characters”. [Arrables, 2009]

Acampora et al discussed a similar framework, wherein game agents should have simulated “personality, likes and dislikes, emotions, [and] moods aimed at improving their human likeness and believability.” [Acampora, 2012] They looked at the way emotions change over time, and are influenced by both impactful events and previous emotional states.

An earlier iteration of this project proposed directly simulating the emotions of the characters exhibiting the experimental behavior. However, over the course of the project the focus shifted to the human perception of emotion in game characters, and whether emotion

could be directly exhibited via behavior.

2.6 Behaviors

While not driven by emotion, Campano and Sabouret described a novel model for believable impoliteness in game agents. [Campano, 2009] Similar behaviors, originating from emotional responses, are important for expanding the scope of the stories games can dynamically tell. Silverman et al extensively discussed means for dynamically generating stories based on game agents' emotional responses. [Silverman, 2006] They paid particular attention to the social connections between game agents. This project similarly tried to implement a novel behavior to improve the believability and relatability of NPCs. Impoliteness, like altruism, is a concept not often seen in games that can make game characters more realistic and lead to more believable game characters.

Chapter 3: Simulation Design

The experiments conducted examined the behavior of two types of NPCs within a predator-prey dynamic. For convenience and communication purposes, this paper typically refers to them as species of fish. These fish were not meant to simulate any specific type of real-world fish. The various behaviors needed to carry out the experiments are described below.

3.1 Flocking

The prey used a two-dimensional implementation of the flocking behavior described by Reynolds [Reynolds, 1987]. Three rules govern this behavior. Prey move away from other prey to prevent collisions. They move toward the center of mass of the flock and match the acceleration vectors of other prey to maintain flock cohesiveness. These three rules combine to produce flocking behavior that mimics that found in nature. Each prey uses them to calculate small adjustments to its acceleration vector on each update.

3.2 Additional Movement Rules

A few additional rules provided even more realistic behavior. A speed limit was set for each fish's velocity vector. (This rule was applied to predators as well). If a fish's velocity exceeded that limit after updating, its velocity was normalized, then scalar-multiplied by the limit. This preserved the fish's direction but restricted its speed.

Prey moved strongly to avoid predators within their limited field of view. This adjustment to their update vectors was significant enough to temporarily disrupt their flocking behavior. While this was necessary to avoid being eaten, there were scenarios where it could backfire. If multiple predators were hunting prey in close proximity, they sometimes clustered more tightly,

making it easier for predators to eat several at once.

Both predators and prey were encouraged to stay within the bounds of the world. If they moved outside of the bounds, a small update to their acceleration pushed them back into bounds. This kept the fish generally within the bounds of the world, without causing them to bounce off of an invisible world border. In early tests, that bouncing behavior was both unrealistic and put the prey at a strong disadvantage when trying to avoid predators.

3.3 Food

Predators had a hunger level and hunted for prey to eat when it dropped below 40 percent. Food for prey was simulated by capping the number of prey that could exist in the world. If the prey population rose to twice its starting population, 10% of the prey immediately starved to death. This simulated the number of fish that could survive in the world based on an assumed but otherwise not simulated food source. While somewhat unrealistic, this simplified the simulation and allowed more attention to be directed to the research questions at hand.

3.4 Hunting

When a predator became hungry it would target the closest prey. In order to keep it from changing its target at almost every update, it would not update its target unless a new prey was less than half the distance of its original target at the time it targeted it. Prey in the experimental group capitalized on this fact to enable their altruistic behavior to distract predators from their original intended prey by getting closer to the predator.

3.5 Age

Fish behavior was tied to their age in a way that was meant to generally mimic the real world. Fish could not reproduce before or after a certain age and would die of old age. Older prey were more likely to engaging in the sacrificial distracting behavior described below.

3.6 Speed

Predators moved 25% faster than prey. Tests were conducted where the prey moved faster or at an equal speed to the predators. The entirety of the predator population died in short order in every one of these tests.

3.7 Reproduction

Predators and prey reproduced asexually. While two-partner reproduction might be more interesting, that would imply an evolutionary genetic algorithm that was beyond the scope of these experiments. Predators and prey originally had their own reproduction rate variables, shared statically amongst all members of their respective classes. They were evaluated once per turn against a randomly generated number between 0 and 1. If the number was less than the reproduction rate, the fish created a new instance of its subclass. That new fish could not reproduce until enough cycles had passed that it reaches maturity.

It was anticipated that steady-state reproduction rates could be found that would lead to a stable world by iteratively testing and adjusting reproduction rates. This was not the case. The simulation was chaotic, with no clear relationship between changes to the reproduction rate and the stability of the populations. Either the number of prey would get so low that all of the predators would starve to death (after which the prey population would tend to slowly rebound)

or all of the prey would be eaten, again leading to the subsequent starvation of the predators.

Attempts were made to counter this by varying both the starting points and variation amounts of the reproduction rates in the iterative testing process, but the simulation remained chaotic and the populations inevitably died out every time. This mirrors May's description of the logistic equation that describes population growth is sensitive to chaotic behavior [May, 1976]. Interestingly, the only consistent result was that altruistic behavior tended to make the simulation last longer.

The simulation was then modified so that both predators and prey would give birth on regular time intervals. This led to a simulation environment that was stable for a longer period of time. While the prey population tended to be overwhelmed either time, it would take two to three times longer for this to happen.

3.8 Altruistic Behavior

When a predator targeted any prey, the oldest available prey navigated away from other prey and directly toward the predator. Since the predator targeted the closest prey (not excepting the caveat discussed above) it would update its target selection to hunt the distracting prey moving toward it. Once the distracting prey got close to the predator it would change its behavior and try to flee. There was still a high chance it would be eaten. Nonetheless, this distracted the predator from its original prey. Since the distracting prey was always chosen from the oldest prey in its flock, this meant that younger goldfish were more likely to survive.

Only one fish would distract any given predator at a time. Once a fish was distracting a predator no other prey attempted to distract for the original distractor.

3.9 Vision Limits

Prey had a limit on their vision so that they only flocked with other prey and only fled from predators in close proximity to them. They had a lesser limit on their ability to distract, so that they would only distract for prey in their flocking group but could see prey targeting a group member at a great enough distance to have time to distract the prey. Predators had no vision limits.

Chapter 4: Methods/Procedures

The sections below describe the classes that were developed. For more information, please refer to the UML Class diagram in Appendix A below.

4.1 Fish

All decision-making AI agents in the game are fish. This parent class contained numerous attributes and behaviors that its child classes inherited. Vectors and points that stored a fish's velocity, acceleration, and position were class attributes. The Fish class contained code to keep fish within the world space, and encourage them to return if they ventured out of it. This class also contained code to draw fish on the screen, including logic to perform an affine transformation to rotate the fish based on its current velocity vector.

4.2 Prey

The prey and predator classes inherited from their parent Fish class. Prey flocked according to a two-dimensional implementation of the Reynolds algorithm, as described above. [Reynolds, 1987] They shared inherit reproduction code from the parent Fish class. They had a slightly slower maximum velocity than the predators, so that it was possible for them to be caught and eaten. When not distracting, they fled any predators that came too near to them.

4.3 Predators

Predators could identify the closest target and hunt them. This included an intersection test to see if the predator's position overlapped that of the prey it was hunting. They shared reproduction code with the prey, inherited from the parent Fish class. They had a slightly faster

maximum velocity than the prey, so that it was possible for them to catch food. Predators wandered around the screen when they were not hunting food, as described in [Buckland, 2005]. A much reduced wander vector was also added to their hunting update vector, in order to keep them from being too effective as hunters. Without this, the predators targeting the fish caught them almost unrealistically quickly.

4.4 Vector2D and Point2D

The Vector and Point classes defined in the Java standard library were not a good fit for this simulation. The Vector class stores values as integers, which would have resulted in a loss on precision across calculations. It was much more precise to store the components of vectors and points as floating-point doubles, and cast the point components when fish needed integer values to draw themselves on the screen. For this reason, customized Vector2D and Point2D classes were written. The Vector2D class was written to store velocity and acceleration values and perform calculations on them. The Point2D class was written to store fish's positions in the world and compare distances.

4.5 Draw Panel

The draw panel was a singleton class which fish could draw themselves upon. It was used to visually confirm that new behaviors were working correctly and for capturing video of the simulation for Experiment 2, as described below. The draw panel could be zoomed and translated to focus on a particular portion. Drawing on the Draw Panel could be turned on and off during runtime. The simulation could run significantly faster with visualization turned off, and this did not affect data being logged to file.

4.6 Update/Draw Cycle

An update-draw cycle is typical for most videogames and was a good fit for this simulation. All fish in the simulation were updated and their positions in the ArrayList were sorted based on their age to ensure that the oldest prey within a group not already distracting would be chosen to distract hunting predators. Fish flocked, wandered, hunted, fled, fed, reproduced, died, and distracted, as described below. The fish ArrayList was then iterated through a second time, and all fish drew themselves on the DrawPanel if visualization was turned on

4.7 Control Group Design

Creating a world with the number of behaviors outlined above leads to a large number of variables which, when tweaked, can have a noticeable impact on the behavior of the game agents. This creates an overly wide search space to find an optimal control group. To simplify this, all variables besides predator and prey reproduction rates have been fixed at values that combine to function adequately, as confirmed by visualization. The reproduction variables most directly control the size of the two populations relative to each other, and in a successful, stable control group the two fish populations should find an equilibrium where neither group overwhelms the other or goes extinct.

In order to find this, the simulation includes a mode where the program will increase and decrease the reproduction rates by the same amount, modified by a small random number to give some variability across iterations, whenever one of the populations reaches zero or goes over twice its starting value. An iteration counter is reset every time the world resets due to one of the

populations reaching an extremity. If the counter reaches one-hundred thousand, the world is considered to have reached a stable equilibrium. The reproduction rates are written to a text file, the timer is reset, the reproduction rates are reinitialized at their original default values, the world is reset, and the simulation is run again to find new equilibrium rates. After 100 stable pairs of reproduction rates are found, the simulation will end, and the means of those rates will be used to for the reproduction rates in the control and experimental groups.



Figure 1: A screenshot from the software used to conduct Experiment 1. Several groups of orange prey, with predators throughout, seven of which are hunting.

Chapter 5: Experimental Design

Two experiments are proposed to test the hypotheses listed above. The first experiment focused on the effect of altruistic behavior and familiar connections on the performance and survivability of game agents. The second experiment measured the responses of participants viewing footage of the simulation regarding their perception of the emotion-based behaviors and motivations of the game agents.

5.1 Experiment 1 Design

Simulations were run with and without the sacrificial behaviors described above. Each of these tests was repeated 100 times for each group to ensure there sufficient statistical power to show a difference between the two groups. The unit of time for all measurements was update cycles.

Each iteration of the experiment for the control group was paired with an iteration for the experimental group. Initial values for position, orientation, hunger, and age were generated from random seeds created prior to runtime and read from a file. This will ensured that, while randomized, these values were consistent for each paired experimental-control iteration of the experiment. This was done to ensure that differences between the control and experimental groups could be attributed to the altruistic behaviors.

The size of the world was 3000 x 3000 pixels. Fish could swim slightly outside of the boundaries of the world (to present unrealistic bouncing off of the edges), but were gradually pulled back into bounds by adding a vector to do so to their movement update. There was no geometric terrain or obstacles in the world, although this was considered and would be an interesting feature to add to future experiments.

5.2 Experiment 2: Human Perceptions of Altruistic Behavior

Experiment 2 compared the perceptions of humans viewing videos of the simulation and looked for differences in their perceptions of the agents' emotions and motivations. Of particular interest was whether they would view the altruistic behavior as one driven by positive emotion to protect the younger fish in the flock. Two approximately one-minute videos, with and without the sacrificial altruistic behavior, were recorded from footage of the simulation. Participants were asked to complete a pair of survey instruments designed to measure their perceptions after viewing one of the videos, selected at random.

5.2.1 Recruitment and Informed Consent

The experiments were conducted during introductory Computer Science and Information Systems classes at UNCW, with study participants recruited from the classes. Students were free to choose whether to participate or not; it was at the course instructors' discretion whether to offer extra credit to participants. Those who did also provided an alternative venue for earning extra credit so as to avoid the appearance of coercion.

Each of the classes recruited from had two sections. All students within a section who chose to participate saw the same video, chosen randomly before the experiments. The second section then viewed the other video.

Participation rates were good, with 86% of students participating in the pilot study, and 100% of the students choosing to participate in the final experiment. Students who agreed to participate received and signed informed consent documents indicating their willingness to do so.

5.2.2 Instructions to Subjects

Some background and context describing the simulation agents was read to the students over the course of the experiment. The text was later modified slightly from the initial pilot study to the final experiment in order to address some factors participants found confusing, as discussed below. The text of these scripts is included as Appendices (specify).

5.2.3 Survey Instruments

Two data-collection instruments were administered: a free-response item and a five-point Likert survey. The video was repeated after playing it once. Participants were told they were free to begin writing during the second play through. They then had three minutes to freely write about their interpretation of the video. They were asked to pay special attention to the behaviors of the agents and the motivations behind those behaviors.

After three minutes a 13-question Likert survey was distributed to the participants. It was not distributed along with the free-response item so as not to prejudice the quality of the participants' responses. This survey is included as Appendix (specify). Some questions on the survey were designed to test for differences between the two groups (specify, for example) while others were expected to generate roughly identical positive and negative responses in both groups (specify and specify, respectively).

The free-response and Likert surveys were collected together so that participants' responses the two instruments could be considered in tandem.

5.2.4 Experiment Videos

A few changes, generally cosmetic, were made to the simulation to make it easier for

participants to parse the agents' behavior within the time allotted. First, the number of agent at the initialization of the simulation was shrunk dramatically, from 200 prey and 20 predators to 20 prey and two predators. This was done to make the simulation more 'readable' by human eyes unfamiliar with it – 200 predators created too much visual noise for people viewing the simulation to identify individual distraction attempts. For the same reason, the size of the world was dramatically shrunk from 3000 by 3000 pixels to 800 by 800 pixels. This made the agents more immediately identifiable as fish, rather than as vague four-to-six-pixel objects.

5.2.5 Pilot Study

An initial survey was administered with 126 participants. This survey was conducted in an introductory computer science course, as described above.

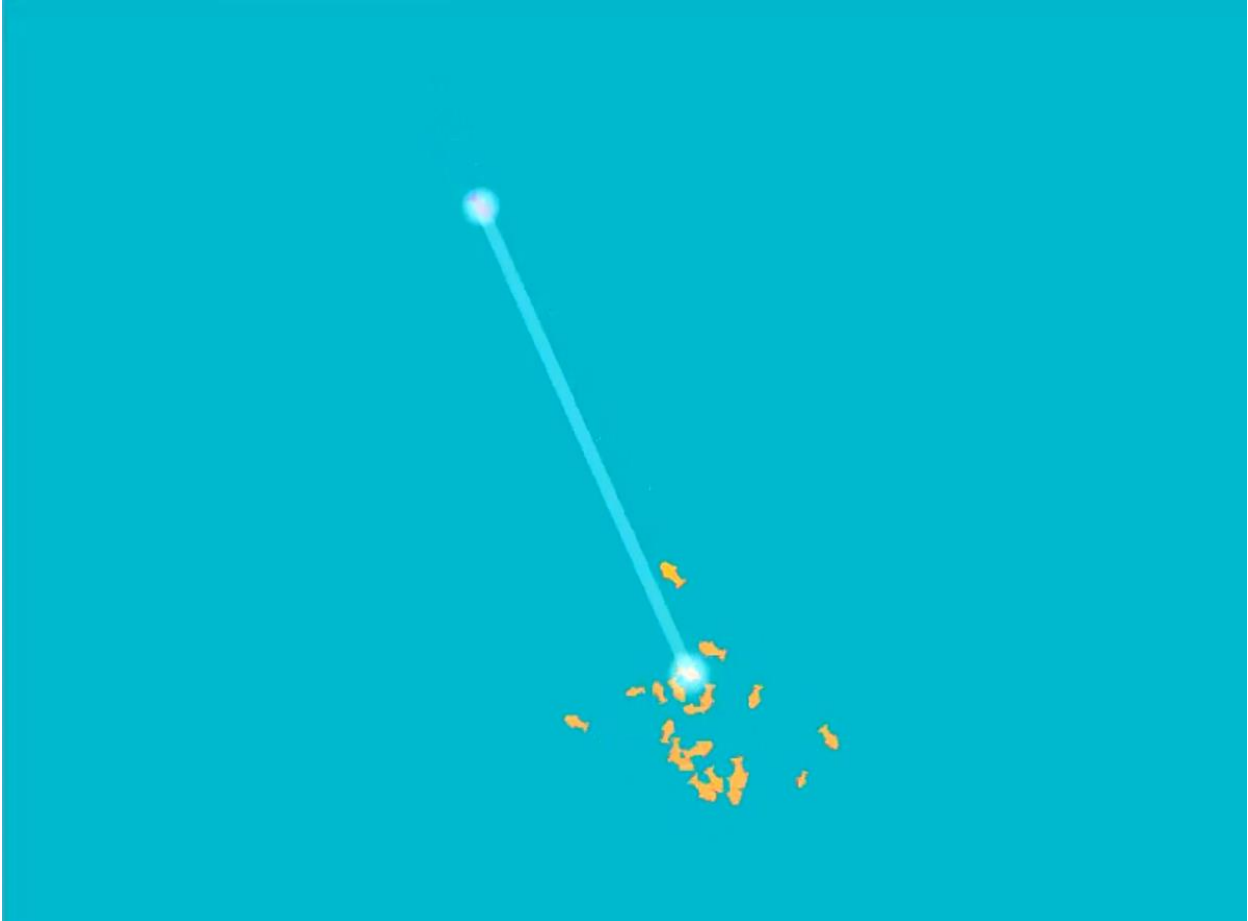


Figure 2: A screenshot from the experimental video shown during the pilot study. A predator is targeting a prey, while another prey is moving to distract it.

5.2.6 Pilot Study Results

The results of the initial pilot study had some interesting results (discussed in greater detail below) but did not support the hypothesis. There were no significant differences between the any of the items on the quantitative survey. There was a difference in the qualitative data that was unexpected. While the number of positive emotional words was about the same, the number of negative emotional words was roughly double in the control group. This seemed to suggest that while the experimental group was not seeing the altruistic behavior as expected, they were seeing something that caused them to view the agents' actions less negatively, even if they were

not aware enough of it to write positively about it. This factored into some of the changes made to the videos for the final study in order to make the distracting behavior more noticeable.

5.2.7 Changes after the Pilot Study

A number of elements in the videos shown were unexpectedly found to confuse participants' perceptions of the game agents' behaviors and motivations. Changes were made to the simulation to eliminate these distracting elements and make it easier for the subjects to observe the interactions between predators and prey.

There were two predators in each scene of the pilot videos, but only ever one predator-hunt attempt. Many participants wrote that they thought one of the rules of the world was that only one predator was allowed to hunt at a time. Some wrote that the predators were coordinating their actions to help each other hunt. To eliminate this confusion, and given that the second predator was superfluous to the behavior being tested on, the final videos only included one predator.

The use of multiple scenes with one predator-hunt attempt in each was confusing to some participants. Many participants assumed continuity between the scenes, since it was not specified that there was none, and speculated on how the agent's actions and motivations in one scene influenced their state, actions, and motivations in the next. To eliminate this, the final iteration of the experiment used a video displaying one long scene with multiple predator-hunt attempts. Production of this scene necessitated a few additional changes.

Predator's hunger logic was changed so that there would be multiple predator-hunt attempts within the roughly one minute allotted for the video. Eating a prey would cause the predator's hunger level to reset to its hunt threshold plus ten percent of its maximum hunger. The

shark would then wander for a short period after each time it ate a prey, generally putting some distance between itself and the swarm. In the experimental video, this had the benefit of improving the probability that there would be enough distance to allow time for the distracting behavior to be noticed.

Some participants in the pilot study wrote that they were confused as to why the shark appeared to be the same size as the fish. The draw size of the predator was increased by 100% to eliminate this seemingly confounding factor. The relative draw size of the prey was also altered so that there would be a greater differentiation in size between younger and fully-mature fish.

Since these size changes were only reflected in the visualization, the length of time it took a predator to catch a prey after it was near to it but not yet intersecting it became increasingly unrealistic looking. The predator's intersect method was therefore changed to allow them to eat prey that were twice the distance away. This looked much more realistic, and the truncation of the amount of time it took a predator to catch a prey allowed more predator-hunt attempts to be completed within the single-scene video.

The repel distance was slightly increased so that individual prey could more easily be differentiated within the group. The intended effect of this was that the existence of smaller, younger fish would be easier to visually identify.

A number of participants attributed interesting characteristics to the tracking line, especially in the control group. Despite its brief description in the instructions read to participants, it was viewed as a laser beam, a tractor beam, or a shrink ray by a number of participants. To minimize this, the spotlights on the targeting predator and targeted prey were removed, leaving only an off-white line between the two. It was necessary to leave some indication of the predator's intended prey; otherwise participants would have no idea when the

predators were hungry, and in the experimental video it would just appear that prey sometimes left the flock.

The game agents were slowed by about 40 percent to make it easier for participants to identify the altruistic behavior. To help maximize the visibility of the sacrificial behavior, the final video was played at 70% of its recorded speed, via a feature in the Quicktime video player used during the experiment.



Figure 3: A screenshot from the experimental video. A smaller, younger prey has been targeted by the predator, while larger, older prey has left the group to distract the predator.

Chapter 6: Results

6.1 Experiment 1 Results

It was demonstrably shown that engaging in the distracting behavior described above was in fact altruistic, in that it was detrimental to the prey engaging in the behavior to do so. Engaging in distracting behavior led to the death of the distractor 94.3% of the time. The only time a distracting prey was not eaten when was the predator was too close to its original targeted prey, not giving the distracting prey enough time to get close to it. However, this self-detrimental, altruistic behavior had a positive impact on both the prey and the predators as groups.

The difference in total number of iterations between the experimental and control groups was even more pronounced with a regular reproduction birth rate. On average, a simulation with the experimental group lasted 4273 iterations longer, a 25% improvement. This affected several other statistics collected, including the mean age of predators and prey and their mean number of descendants.

Because every fish reproduced on the same interval, the number of children per prey and predator was similar between the two groups. However, because the simulation lasted longer, the average number of total descendants for was 33% higher for prey and 26% higher for predators.

There was a small but very statistically significant difference between the mean numbers of children in each group. Prey in the control group had a mean of 0.6 children, whereas in the experimental group they had 0.65 children. While this difference was small, the p-value was extremely small, at 0.0000000000000001303. There was a similar difference between predators; with a 0.65 mean in the control group and a 0.71 mean in the experimental group. The p-value here was even smaller, at less than 0.00000000000000000001.

	Control	Experimental	P-Value
Prey Pop.	502.15 (36.91)	579.28 (70.23)	0.00000000000000002680
Pred. Pop.	58.04 (3.56)	70.41 (4.27)	0.00000000000000000000
Prey Mean # of Children	0.6 (0.03)	0.65 (0.04)	0.00000000000000001303
Pred Mean # of Children	0.65 (0.02)	0.71 (0.02)	0.00000000000000000000
Prey Mean # of Descendants	0.83 (0.08)	1.1 (0.16)	0.00000000000000000000
Pred Mean # of Descendants	0.84 (0.07)	1.06 (0.1)	0.00000000000000000000
Prey Mean Age	5911.36 (206.58)	6590.25 (310.13)	0.00000000000000000000
Pred Mean Age	8974.63 (936.94)	10690.58 (653.33)	0.00000000000000000000
Length of Simulation	17380.2 (1303.44)	21653.64 (4273.44)	0.00000000000000000000

Figure 4: Selected data from Experiment 1.

Prey lived 11% longer in the experimental group. The altruistic behavior had the effect of allowing the younger prey to have a lower probability of being eaten earlier in their life, thus giving them more time to reproduce.

Interestingly, predators lived 19% longer in the experimental group. Prey sacrificing themselves were easier to catch for the first part of the behavior; that some prey attempted to distract every predator targeting another prey meant that no hungry predator was ever far away from a prey.

6.2 Experiment 2 Results

6.2.1 Quantitative Results

There were significant, interesting differences between the two groups on several items on the Likert survey. Most tellingly, there was a significant difference between the two groups on their responses to Question 3, “The goldfish tried to protect each other, even if it put them in danger.” 14 participants in the experimental group either agreed or strongly agreed with this statement, as opposed to 11 who were neutral, disagreed, or strongly disagreed. Eight participants in the control group either agreed or strongly agreed with this statement, as opposed to nineteen participants who were neutral, disagreed, or strongly disagreed. The mean of the

experimental group was 2.52 with a 1.39 standard deviation, as opposed to a 1.37 mean in the control group with a 1.18 standard deviation. The t score for these two groups was 0.001214, indicating a strong statistical difference.

Question	Control	Experimental	P-Value
1	1.7 (1.17)	2.68 (1.25)	0.003
2	1.85 (1.23)	2.48 (1.29)	0.040
3	1.37 (1.18)	2.52 (1.39)	0.001
4	2.37 (1.11)	2.64 (1.04)	0.185
5	1.0 (0.96)	1.2 (0.87)	0.217
6	0.93 (0.96)	1.0 (0.91)	0.388
7	0.93 (0.92)	1.0 (0.87)	0.383
8	0.74 (0.9)	1.08 (1.0)	0.103
9	2.93 (1.0)	2.96 (0.84)	0.447
10	1.22 (0.85)	1.36 (1.04)	0.302
11	1.52 (1.16)	2.24 (1.09)	0.012
12	2.89 (0.97)	3.25 (0.85)	0.082
13	2.07 (0.92)	2.44 (1.29)	0.125

Figure 5: Mean, standard deviation, and p-value data from the quantitative instrument used for Experiment 2.

There was a significant percent difference between the mean responses of the two groups on Question 1, “The goldfish seemed to care about the other goldfish.” with a 0.002769 t-test score. This seems to indicate that more participants in the experimental group saw emotionally-motivated behavior, even if they did not write about it on the free-response questionnaire.

The last question on the survey (“The goldfish cared about the members of their social group.”) was very similar to questions two and three. While there was still a difference between the two groups on this item, it was less pronounced than it was for questions two or three (see the chart below). It may have been the case that having gone through the rest of the questionnaire influenced participants' perceptions of what the experimenting was testing for, causing the

control group participants to attribute more emotional motivations to the prey. It may also have been the case that while more experimental group participants recognized the sacrificial behavior in the goldfish in the video they saw, not as many attributed it to caring about their social group.

The survey questions which were not expected to diverge did not do so. Mean participant responses to “The sharks tried to protect each other.” were 0.93 in the control group and exactly 1.0 within the experimental group, respectively. This is not a significant difference, as was expected. As there was not more than one shark in the video shown in the final experiment it was expected that both groups would disagree with this statement without any real difference between the two.

6.2.2 Qualitative Results

The quantitative data was analyzed using several different affective analysis tools to measure the number of emotional words in the participants' results. While none of these results were different enough to be statistically significant, there were several interesting findings, especially when this data was analyzed in conjunction with the quantitative data collected with the Likert test.

Four experimental-group participants' responses explicitly indicated in writing that they recognized the goldfish's' altruistic behavior as sacrificial. This was 16%, whereas 56% of experimental group participants either agreed or strongly disagreed with Question 3 (“The goldfish tried to protect each other, even if it put them in danger.”) on the Likert survey. It may be that participants' higher rate of indicating that they saw sacrificial or altruistic behavior on the Likert survey may be a result of reading the survey items and having their responses colored by them.

Interesting, three of the four of the experimental-group participants who wrote that they saw sacrificial behavior interpreted it as a behavior of the group of goldfish, collectively. Generally their responses seemed to indicate that the group expelled or sacrificed a member when a predator was targeting a group member. This may have been a result of participants viewing the group of goldfish as a single entity, not as a collection of individuals. It may be that this was due to the strong visibility of the flocking behavior. Outside of the distracting behavior the goldfish never acted outside of the flock.

6.2.3 Quantitative/Qualitative Results

In order to further explore this, the free-response writing of experimental group participants was segregated based on their responses to Questions 3, “The goldfish tried to protect each other, even if it put them in danger.” The LIWC tool was used to analyze their writing. The results with an interesting difference are below.

	Family	Humans	Affect	Pos Emo	Neg Emo	Anxiety	Anger	Sad	Inhibition	Religion
Control	0	0.22	2.81	1.21	1.6	0.44	0.55	0.39	0.99	0
Neutral, Disagree, or Strongly Disagree	0.12	0.3	2.36	1.27	1.09	0.24	0.6	0.12	0.48	0.12
Agree or Strongly Agree	0.21	0.31	1.88	1.05	0.84	0.21	0.52	0.1	0.31	0.21
Strongly Agree	0.32	0.48	2.08	0.96	1.12	0.32	0.64	0.16	0.48	0.16

Figure 6: Sentiment analysis of free-form text from Experiment 2. Participants’ qualitative data was grouped by their response to Question 3 on the quantitative instrument and analyzed using the LIWC tool. Categories with strong differences are shown here.

The number of ‘Family’ words went from zero in the control group to 0.12% in the neutral-disagree group, and continued to increase the more participants agreed with Question 3.

This implies that participants who saw the altruistic behavior tended to view the group of prey as family, and did so more strongly the more explicitly they recognized the implications of the behavior. The 'Human' words category also rose, though less dramatically. Though there was no difference between the neutral-disagree and agree categories, the strongly agree category is much higher.

Interestingly, affective words, positive emotional words, and negative emotional words all dropped from both the neutral-disagree category to the agree category. Taken in tandem with the increasing 'Family' and 'Human' results, it may be that participants associated stronger emotions the less they saw or consciously saw the altruistic behavior due to the no-graphic but still ever-present violence in the predator's behavior.

Chapter 7: Discussion

7.1 Altruism

The altruistic behavior shown here is likely Darwinian, even if that is not immediately obvious. The distracting prey was eaten in almost all cases, which at first seems to contradict the idea of “survival of the fittest”. However, the fact that the prey that were eaten were older ensured that were eaten by predators were more likely to be prey that had already reproduced. Prey that had already had many children had a chance to distract for their children. Even if they did not, some other, older prey distracted for their children, while they distracted for another prey's children. Cooperation (even if only implicitly) seems to be useful, even if it comes at a steep cost to the distractor.

7.2 Applications for Games

The experimental altruistic behavior described above has numerous applications in game development. A few possible uses are described below.

7.2.1 Crowd Behavior

Shooters, role-playing games, massively-multiplayer games, and strategy games all tend to simulate the behaviors of individuals in groups in large battle scenes. The altruistic behavior tested here could add levels of realism these types of games. NPCs acting altruistically to each other in battle scenes or other dramatic scenarios could seem more human and be viewed as being more concerned with each others' welfare. Players of such games might feel more strongly that the NPCs are invested in their group membership.

7.2.2 Computer-Controlled Cooperative Players

Many contemporary games feature cooperative play, allowing two or more players to play together through the game's campaign against the computer. These games sometimes use a computer-controlled player to control the cooperative partner or partners in order to allow single players to still play the game. If the altruistic behavior tested here were used by the computer controlled cooperative player it could provoke an emotional response in the human player and make the game scenario and the computer controlled characters seem more realistic and lifelike.

7.2.3 Procedural Story Generation

The fact that participants in Experiment 2 used more human and family words to describe the experimental NPCs could imply that participants would recognize altruistic game characters as being more human-like. It also could imply that game players would be more likely to recognize the interaction between game characters as based on or motivated by familial connections. If those characters were placed in defined inter-character social networks where the actions of one character influence the emotional state and actions of other characters, that could be used as a tool to procedurally generate dynamic and unpredictable stories in games.

The question remains whether this could be done as the game is running, or whether it should be used as a tool for game developers to generate a number of possible scenarios and choose those they most prefer to put into their games. It is possible that some hybrid form of this system could exist, where initial conditions and an array of possible milestones are scripted, but the story in between and the final outcome are unpredictable.

Chapter 8: Conclusions

8.1 Hypothesis One

Hypothesis One theorized that:

Adding self-sacrificial, altruistic behaviors to NPCs exhibiting flocking behaviors will impact the behavior of the flock by affecting variables such as population count, mean age, and ratio of prey targeted to prey eaten.

The experimental groups in Experiment 1 had a greater population count and mean age, along with increases in other variables such as mean number of children and total number of iterations in the simulation. The hypothesis was valid, based on those metrics. The same cannot be said for the ratio of prey targeted to prey eaten. Predators that targeted a prey ate a prey in almost every instance; most scenarios had zero predator deaths due to starvation and no scenarios had more than one. The altruistic behavior really was altruistic in that it led to the death of the distractor greater than 94% of the time. The major difference to the state of the prey as a group was that younger prey were eaten far less frequently. Given this, in retrospect, ratio of prey targeted to prey eaten was not a good measurement of the impact of altruistic behavior.

8.2 Hypothesis Two

Hypothesis Two theorized that:

Humans viewing the self-sacrificial behavior will view it as altruism and will attribute emotional motivations to this behavior.

The quantitative data confirmed this hypothesis. Participants in the experimental group were much more likely to agree with statements such as “The goldfish tried to protect each other, even if it put them in danger.” and “The goldfish cared about the members of their social group.” The results from qualitative data were more mixed, but no less interesting. Participants tended to

write more affective words about the control group, but those words were often more negative. Participants in the experimental group used less affective words, but more family, group, and human associated words. A number of participants recognized the sacrificial behavior, but attributed as a function of the group of prey. This result was completely unexpected, but understandable upon reflection. Since all of the preys' other visible actions reinforce their status as members of a group, it is understandable that some participants imparted group motivations to new behaviors.

8.3 Implications of Results

Adding altruism to groups of NPCs has a definite impact on the state of those NPCs and the world they inhabit. It changes the makeup and survivability of groups that implement this behavior, their interaction with other, dependent groups, and the makeup and survivability of those groups. Game creators can add further richness and complexity to their worlds by implementing this relatively straightforward behavior.

Game creators can successfully elicit player responses by adding altruistic behavior to their NPCs behavior sets. While further experimentation will be needed to be able to more reliably predict what responses players will have, this paper lays groundwork for building an understanding of the way game players interpret altruistic behavior, particularly as it relates to groups and individuals.

8.4 Future Work

Earlier in this research project there was a plan to examine the effect of altruism when the probability of a prey to distract was modified by its degree of relatedness to the prey being

targeted. This experiment was not conducted due to scope issues and confounding issues from studying altruism and degrees of relatedness at the same time. It would be interesting to conduct this experiment, as altruism modified by relatedness across social networks could potentially allow for the creation of even more richly-detailed game worlds.

It would be interesting to conduct a variation on Experiment 2 wherein participants had direct control over a predator using a game controller, mouse and keyboard, or touchscreen, instead of viewing footage of the simulation. The quality and caliber of their responses might change if they directly had control over the actions of the predator. If data collection could be automated by recording their gameplay, the game could be made available for free over the internet, potentially allowing the collection of a very large amount of user data with a great diversity in demographics.

The attribution of sacrificial behavior by some participants to a group versus individual decision was an interesting and unexpected finding that bears further investigation. One future experiment could compare two groups with altruistic behavior, but with one group not exhibiting flocking behavior. It would be interesting to compare the proportions of human subjects that attributed altruism to a group versus an individual decision across these groups.

It may be that some participants who saw the distracting behavior but did not speculate on the preys' motivations for engaging in it were unable to relate to the prey or predators as agents capable of making complex or emotionally-motivated decisions. It could be interesting to rework the simulation environment to include more detailed, anthropomorphic graphics for the predators and prey. The results of such a study could potentially be compared to the results of this study.

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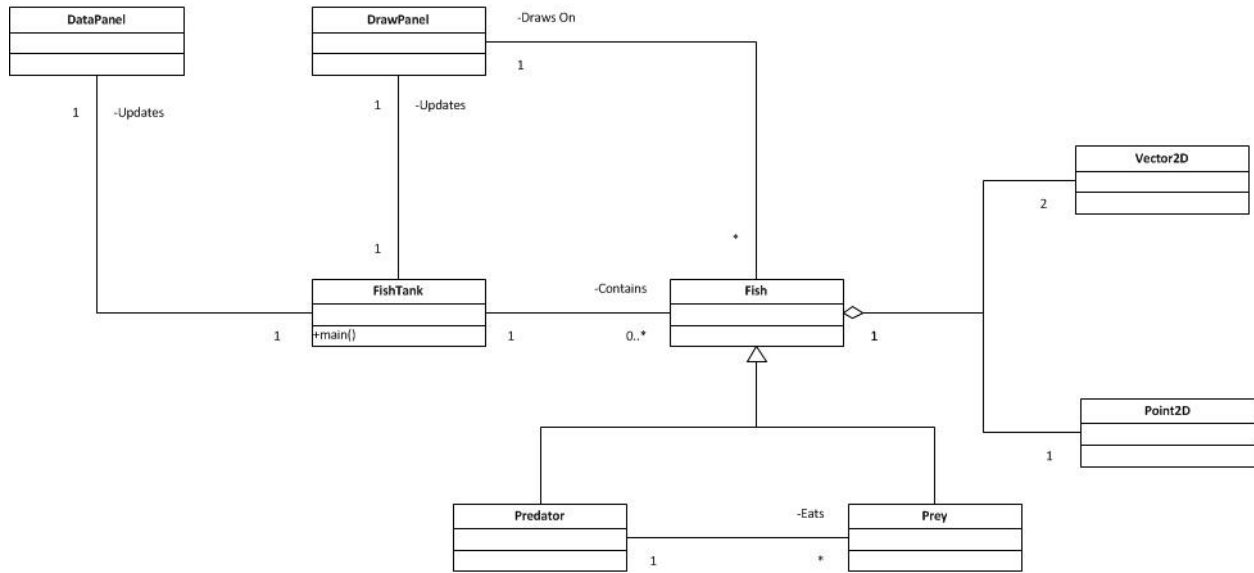
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Appendices

Appendix I: Fish Tank Class Diagram

Fish Tank Class Diagram

Methods and parameters omitted for clarity and brevity.



Appendix II: Instructions to Experiment 2 Participants

//Distribute informed consent and free response page while reading this
Good morning everyone,

I'm here today to ask you to participate in an experiment we are conducting regarding an in-development game project. I'd like you to watch a short video I've edited from the game, and fill out a pair of short surveys describing what you see. You are free to choose whether or not you'd like to participate in this experiment. While there is no direct benefit to you, there is no risk either. Declining to participate will not affect your grade in this class or other classes in any way. The video is not in any way graphically violent. We expect this experiment to take around ten minutes in total. If you choose to participate you will be asked to sign an informed consent document, acknowledging what I've just told you and indicating your willingness to participate.

The video we are going to show you is of a prototype for a game we are developing. The game has very simple graphics and we aren't looking for feedback on them at this stage. There are two types of game agents in the video, sharks and goldfish. Sharks are blue and goldfish are orange. Sharks will hunt the goldfish when they are hungry and try to eat them. If they aren't hungry they wander around the screen. The goldfish will flock together, and will try to avoid the sharks.

You may see other behaviors in the video. If you do, please describe them to us. We'd also like your feedback on what, if any, emotional motivations you see influencing or driving the game agents' behaviors.

You will view a short video, approximately one minute in length. Since it is short we will play it twice. Afterward we will ask you to write for three minutes about what you saw. You can write as little or as much as you want. There are no right or wrong answers. Afterwards, we will distribute a short multiple choice survey about your interpretation of the video. Again, there are no wrong answers here; we are only interested in what you think.

Since we will be conducting this experiment across several classes and we want everyone who takes part to have the same information, we will not be able to answer any questions about the nature experiment before you participate. After all data has been collected we would be happy to discuss it with any interested students. Please come see me, Dan Palmer, in the MSCSIS grad lab if you have any questions after about three weeks. I'd be happy to discuss them then.

//Distribute the informed consent and free response pages
I will now play the video. Since it is short, after it has finished I will play it a second time.

//Play the video
Please take the next few minutes to write about what you saw in the video.

//Wait three minutes
Thank you. We are going to collect your responses now. If you chose to participate, please take a copy of the second survey, and fill it out. The experiment will be over once you've finished it.

Appendix III: Informed Consent Document

Consent to Participate in a Research Study **Perception of Artificial Game Agents**

What Is The Research About?

You are being invited to take part in a research study about human perception of computer game agents. If you take part in this study, you will be one of about 150 people to do so.

The person in charge of this study is Dr. Curry Guinn (PI) of the University of North Carolina at Wilmington. UNCW student, Dan Palmer, will be gathering and analyzing the information for the study. None of the researchers participating in this study stand to gain financially or personally.

During class time, you will be shown a short (approximately one minute) video of a game in development. You will then be asked to describe in writing the behavior you observed in the game. Once you have finished writing you will take a short survey with questions about what you saw in the video. There are no known risks to participate in this study. There is no personal gain for you to participate in the study other than the satisfaction of knowing that your input is valuable for a research effort involving computer games.

Do I Have To Take Part In This Study?

If you decide to take part in the study, it should be because you really want to volunteer. There will be no penalty and you will not lose any benefits or rights you would normally have if you choose not to volunteer. You will not be treated differently by anyone if you choose not to participate in the study. You can stop at any time during the study.

Who Will See The Information I Give?

Your information will be combined with information from other people taking part in the study. You will not be required to submit your name or any other personal information besides your gender and your age. When we write up the study to share it with other researchers, we will write about the combined information. You will not be identified in any published or presented materials.

What If I Have Questions?

Before you decide whether or not to participate in the study, please ask any questions that come to mind now. Later, if you have questions about the study, you can contact the investigator, Dr. Curry Guinn (PI) at (910) 962-7937. If you have any questions about your rights as a research participant, contact Dr. Candace Gauthier, Chair of the UNCW Institutional Review Board, at (910) 962-3558.

Research Participant Statement and Signature

I understand that my participation in this research study is entirely voluntary. I may refuse to participate without penalty or loss of benefits. I may also stop participating at any time without penalty or loss of benefits. I have received a copy of this consent form to take home with me.

Signature of person consenting to take part in the study

Date

Printed name of person consenting to take part in the study

Name of person providing information to the participant

Date

Appendix IV: Experiment 2 Free-Response Survey

Gender (please circle): Female Male

Age: _____

You have just watched a video where sharks (the blue fish) chase and eat goldfish (the orange fish). Imagine you had to describe the behaviors and motivations of the two kinds of fish to someone who has not seen them. In the space provided below, please describe the behaviors and motivations you observed. Please be as descriptive as possible. You will have 3 minutes to record your observations.

Appendix V: Experiment 2 Likert Survey

Gender (please circle): Female Male

Age: _____

Please rate your agreement or disagreement with the following statements by circling the appropriate option.

1. The goldfish seemed to care about the other goldfish.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
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2. The goldfish tried to protect each other.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
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3. The goldfish tried to protect each other, even if it put them in danger.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

4. The goldfish seemed to dislike the sharks.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

5. The sharks seemed to care about the other sharks.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

6. The sharks tried to protect each other.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

7. The sharks tried to protect each other, even if it put them in danger.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

8. The sharks seemed to dislike the goldfish.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

9. The sharks are good hunters.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

10. The goldfish are good at evading the sharks.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

11. The goldfish are good at distracting the sharks.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

12. The goldfish formed recognizable social groups.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

13. The goldfish cared about the members of their social group.

Strongly Disagree	Disagree	No Opinion	Agree	Strongly Agree
----------------------	----------	---------------	-------	-------------------

Appendix VI: Free Response Results

Control Group

1. It shows how the shark has to focus in on one single fish in the school while hunting, and does not just attack the school as a whole with no strategy. He must separate himself from the school to then be able to focus in on a single fish.
2. The shark would go for one specific fish at a time and then would leave the group before targeting another fish. The goldfish seemed to always stay together in the group and didn't separate.
3. The shark targets one goldfish in the pack of goldfish each time and chooses it from a distance. Then it eats that goldfish and only that one even though it is in the pack of goldfish. It then gets a little distance from the group and targets another goldfish and eats just it. This is a repeating process where the shark only eats one goldfish at a time.
4. I saw the blue fish lock on to certain targets and only went for that target even if comparable objects were more easily accessible. As the blue fish locked on the yellow fish seemed to move faster and away from the blue fish. I would describe this to some one as a big fish targeting individual small fish out of a group one at a time and seemingly having tunnel vision until it eats its target.
5. When the shark became hungry it would chase the closest fish (regardless of size) and would only eat that fish. The fish would stay in a group and would not flee, even when the shark was in the middle of the group. The fish being hunted would not notice until the shark was right on it and only then seemed to try to flee. The fish were constantly moving within the group but the group location would not change until the shark came through and pushed the group somewhere.
6. The sharks which were the blue fish were afraid of the goldfish as a while, because they appeared to be a bigger fish. However, the shark seemed to know to go after the smaller fish first and leave the larger ones for last picking them off from the outside making the orange group smaller and closer to the blue sharks own size. Also, the size and number of the orange fish looked to constantly change no matter how many were eaten.
7. Blue fish - It was only determined to eat the fish it had set he target on. It would scope out a fish and attack one at a time to prevent a failure / let down from occurring. Group fish / goldfish – they would scatter about as if to create chaos and distraction for the shark.
8. In the video, a singular lone blue (large) shark fish, hunts and eats smaller goldfish. The goldfish travel together in a unit, like a pod or like birds in a flock. The large shark fish targets outlying goldfish and swims through the swarm of goldfish until he reaches his target and consumes it. The small goldfish scurry away in this process, somewhat frantically, until the shark has left, and they form into a new – smaller by one fish group. The shark backs away, reevaluates the situation, and the process happens again.
9. There is a school of goldfish in a ball in the center, and a shark circling around them. The shark then pinpoints one single goldfish and swims at him to eat him, but leaves all the others alone. When he is done with that fish, he swims away from the ball of fish and then pinpoints another single fish and does the same thing. This is repeated. The shark does this to be consistent and save energy, and the fish stay in a group.
10. The shark targets mostly younger, smaller goldfishes. Once he sets his sights from afar, he pounces on the fish, circles back around, and leaves. The shark repeats this process

multiple times. The fish seem fearless. They all stay together when the shark comes lurking.

11. Shark: Goal: to eat the goldfish. Attempted to gain access to the goldfish by working his way into the middle of the circle and eating one goldfish at a time. Goldfish: Goal: to not be eaten. Stayed together in a group.
12. The shark got its sights set on one particular goldfish and did not stop until it had eaten that fish. Even when other goldfish were closer to the shark, and therefore more easily obtained, the shark still only went after the fish it first targeted. The goldfish always stayed in a group and sometimes even surrounded the shark, but one fish never strayed far. The shark, however, swam around some before targeting a new fish each time. It was also clear that there was only one shark in the video “hunting” alone.
13. The orange fish tend to try to stay clustered. The blue fish only goes for one fish every time he attacks. The blue fish, after hitting his target tends to swim away and circle the cluster until he singles out another fish. The orange fish surround the blue fish when it comes in for an attack. There is no pattern of swimming with the orange fish, it tends to be sporadic and random.
14. The shark will swim by the school of fish targeting weaker / smaller fish on the outer edges of the school. The school of fish stay together and battle their way to the middle of the school for most protection. The fish that don't make it to the middle are typically the firsts to go. While the shark targets a specific fish, it does not deviate to other target until it has eaten it. The shark will then regroup and target a new fish.
15. I would like to play the government as a shark and the citizens as goldfish. The goldfish is under control of the shark. One government can do everything they want, because the power is in their hands but they should be careful if they don't watch out the reaction of citizens.
16. Blue fish targeted one orange fish at a time while the orange fish scattered away once the blue fish was near. Orange fish also surrounded the blue fish when it attacked them.
17. The goldfish seemed scared individually when they saw the shark coming, but when they saw it targeting only one goldfish, they surrounded it but backed away after the one goldfish was eaten. The shark was very motivated to get the one goldfish he targeted but back away from the rest after he obtained his target. The goldfish did not seem motivated to do anything but get away from the shark.
18. The sharks main goal was to eat as many goldfish as he could. The goldfish were trying to swim out of reach so the shark could not eat them. Once he moved in on one goldfish, the others would frantically swim to avoid the shark. The shark would swim away, allow the fish to group back together and attempt it again.
19. The shark targeted what seemed to be the closest fish at a random time and proceeded to eliminate the specific target. The same process happened for three – four targets.
20. The goldfish stay in a group. The shark ignores the goldfish until it is hungry. When hungry the shark targets the nearest goldfish, regardless of size. When the shark chases a goldfish the entire pack of goldfish try to avoid it. After the shark catches a goldfish it removes himself from the group.
21. The shark picks a target and is only interested in it. It swims around by itself and only interacts with the others when hungry. The shark is motivated when hungry. The goldfish tend to swim around as a group and only briefly separate when the shark comes in to attack and feed.

22. The shark acts lonely. Goldfish are always in groups. Sharks get hungry easy. Goldfish are not smart fish. It is really easy to eat the goldfish for the shark. Goldfish live in groups but forget each other easily.
23. The shark shift quickly throughout the water twisting and jerking its body left and right until it sights capture or lock onto a fish. The shark then follows the fish's course until it is eaten. Fish move together in a group. Almost squirming through the water. Their movements are also jerky. They do not necessarily run from the shark instead they just make room for it. They almost accept that they would be chosen for food.
24. Shark appears to be "herding" the goldfish up to the top right corner. Goldfish are not acting in an organized manner. Shark does not single out the largest goldfish to eat. Also does not continue to eat once it has entered the school of goldfish. It swim out and then attacks again.
25. The behavior of the predator is that he finds one fish to eat at a time, and ignores all the other fish, except for the one he zoned out. The fish remain frantic the entire time. He went for medium sized fish and always swam back through the fish after eating. May to help find his next prey. The shark circles back frequently.
26. The shark targets fish that are outside of the school. All the fish simultaneously have a desire to flee the shark and stay with the herd. Once a fish is targeted, the school of fish makes no attempt to protect the solitary fish but instead flee in all directions, forming a semicircular safety barrier around the shark for their own protection. Once the shark has left the area, the school of fish rejoins as a group. If the shark picks a fish outside of the group and the fish flees away from the groups, it swims as fast as it can (abandoning the safety of the group) until the shark loses interest and targets an easier meal. The fish then quickly rejoins the group.
27. The orange fish swam closely together in a group. Then blue fish casually swims by as he targets which orange fish he chooses to eat. When he finds his target he goes directly into the circle of orange fish and attacks his chosen fish. He proceeds to exit the circle of orange fish as they proceed to gather back into a circle. The blue fish keeps his distance as he targets his next victim. Again once he has found which orange fish he wants to go after he swims directly to the circle of orange fish and eats his chosen fish and again leaves the group of fish as they huddle back into a circle. This process continues until the blue fish has eaten all of the orange fish.

Experimental Group

1. The shark has the intention to eat one particular fish in the group only because it is the closest one to the edge of the circle. If a fish strays away from the circle and it happens to be closer to the shark than the target prey changes. The shark only goes for the easier target. When the shark is not hungry it wanders the screen.
2. The shark's movements and actions seemed rather random. The shark would fixate on a target until it got closer to the school and would change to the closest (relatively easiest) target. The goldfish stayed clustered together for the most part, never straying from the school. The shark swam through choosing only one to eat and would leave immediately after.
3. The orange fish always stay together swarming in a small circle. Whenever the blue fish targets an orange fish from the orange circle, a bigger orange fish always swims out to sacrifice itself. The baby orange fish never swam out to be eaten.

4. In this video there is a shark and a group of goldfish. At first the shark just wonders around, but when he is hungry he targets in on a fish. When the shark swims toward his targeted fish his target changes to whichever fish is closest to him. After he eats the fish he goes back to wandering around until he is hungry again, then some thing occurs.
5. The shark would just wander around. Then once it becomes hungry it will aim at a fish inside the school of fish that had been wandering around also. The shark would go towards the fish it is targeting. As it approaches the school one goldfish goes out towards the shark. The shark then turns its attention to the new fish. That fish is then eaten. The shark always goes after the fish that is closest to it. After eating the shark wander around again.
6. The shark would swim around and when hungry would target a certain fish. He would go for only that fish unless another fish got closer. This process continued throughout.
7. A group of orange goldfish looking fish are swimming around in a group while a blue shark is swimming around the outside. The shark is eating the goldfish and every time a fish is eaten he swims back out to the outside and then comes back in for another target. However, the shark never ends up eating its original target that it spots when it's on the outside.
8. The blue fish targets fish and eats the biggest one it can find. It seemed like the group of fish would always find their way back around the big fish. Its almost like they were attracted to the big fish. The big fish definitely knew what he was doing as far as meal size went. All the big fish had to do was locate the group and it would end up with a medium size meal.
9. Behaviors: sporadic, one fish then leave, no specific size, stays toward outside, doesn't change target fish once in pursuit. Motivations: Food, satisfy need for individual fish as opposed to multiple at once.
10. The goldfish appear to solely try and stay in the group, as their defense against the shark (blue fish) seemly is defense in number and / or playing the odds. The shark seems to target any fish that separates from the group. As it closes in on its target it will change targets if another goldfish become more conveniently placed (closer and easier to catch then first target). After eating the shark will then distance itself from the group of goldfish and restart its adventure once another target separates itself from the group.
11. The shark in the video would path find towards a fish in the school, and, on the way over, if another fish became closer, would change and hunt the closer fish. The fish in the video stayed in a small school whilst the shark swam around. If the shark swam towards the fish, the fish would swim away, the shark was faster than the fish, so it would always eaten its prey.
12. The goldfish appear to generally remain confined to a group, while the shark roams freely. When the shark attempts to eat a goldfish, it often does such by establishing direct line of sight with a goldfish which has strayed from the pack. Upon a "shark attack" the goldfish look as if the surround the shark.
13. The shark waits little before eying his prey. He chooses one fish and locks sight on it. As he locks sight, the shark begins to approach the fish in the group. While approaching the fish, another fish will leave the group and it will switch targets to that singled out fish and attack them. The shark does not eat the same fish it originally targets. Uses a sort of surprise / fake out strategy.
14. Although occasionally the shark went to the center of the school and ate one fish, it

usually looked like the shark targeted on fish in the group and swam towards the group. A goldfish would usually then stray from the group and then the shark would eat that one like it was easier to hunt one that had strayed from the group.

15. Wherever the shark goes after a goldfish, another goldfish swims away from the group and usually gets eaten because they were alone. The shark doesn't care which fish it eats because it just wants food. The goldfish want to survive so they either stay together or swim away.
16. The shark was an opportunist. Whenever a fish came closer the shark changed its mind and went to the closer fish. The goldfish seemed to be releasing one of their own so the shark would not intrude any further on the group.
17. The shark swims towards the group of goldfish, hoping to intimidate the group. Each time the shark swims towards the group of goldfish, one strays away from the group. The shark then targets this goldfish, instead of targeting the entire group. This makes it an easier kill for the shark. The shark then swims away, stalks the group, and repeats the process.
18. The goldfish travel in a pack. The shark scans for the pack. The shark only eats one fish at a time, until it rescans. The shark doesn't necessarily eat the scanned fish, just the first one it comes into contact with in the pack.
19. The goldfish swim in a tight group with bigger ones on the outside and smaller ones on the inside. The shark swims around and targets one of the goldfish. The target changes once a better opportunity presents itself when an untargeted goldfish swims closer to the shark then becoming the prey. The shark only eats the targeted fish and then swims away. Process is repeated.
20. The goldfish seemed to have no influence on the way the shark was pursuing his eating habits. The shark tended to vision one goldfish at a time. The shark never attempted to eat each goldfish at once that was of close proximity. It also began chasing its indicated goldfish only to run into another one that was in his way in the process. All goldfish were close together and never broke out of its group unless chased.
21. Sharks do not necessarily chase closest or biggest goldfish. Goldfish do not recognize / fear shark from a far away distance. Goldfish remain in a confused / conflicted pact. Shark goes away from the group of fish and then returns to catch its next, rather than eating multiple at once or in one trip. No goldfish retreats individually from the group of goldfish, or when it rarely does it is more likely to be eaten. It takes a little while for a shark to decide to hunt another fish, even if it is closer.
22. The goldfish travel in a pack while the shark is by itself. The shark eats one goldfish at a time. The goldfish follow the shark while he is going away from them. At first, when the shark is going to eat the goldfish they all try to swim away but eventually they stay put and sacrifice one of their school. The shark swims a straight path when going to eat a fish but otherwise he swims in a random / loop-like or zigzag path. The goldfish huddle closer together when shark is trying to attack them.
23. The shark locates a target at random. As the shark heads towards the target a fish will get in front of target and the shark will switch targets and go for the fish nearest. The fish all swim together to perhaps appear bigger in size than they really are. The fish may be sending one fish out to distract shark as the others attempt an escape. The shark seems to be randomly selecting the fish and attacking in waves.
24. As the shark had located its target and it was evident which he has chosen the group of

fish sent out some sort of decoy fish to distract the predator in attacking the original target. The initial target seemed to be a smaller baby fish which is re reason that a bigger guardian or father fish was sent out to satisfy the shark foe the little while that it did. This worked because the shark still ate food and changed his target each time to the decoy fish, sparing the baby fish. The big group of fish acted as a family.

25. Shark hones in on a fish but changes mind after it see one close. The goldfish stay schooled for most part. Move away from shark mostly. Shark shows no preference in size of goldfish. Shark seems random when not hungry. Some goldfish will stray from school.