TABLETOP ROLEPLAYING STRUCTURE FOR SIMULATING ACTIVE-SHOOTER EVENTS

by

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ABSTRACT

MATTHEW HAWKINS. Tabletop Roleplaying Structure for Simulating Active-Shooter Events. (Under the direction of Dr. MIRSAD HADZIKADIC)

This research presents a structure based on tabletop roleplaying for creating better computational models for simulating active-shooter events. Active-shooter events involve one or more people actively trying to kill others inside a populated and confined area. Roleplaying is the act of human participants portraying characters in a simulated environment. Roleplaying can be used for serious purposes, such as simulating real world events. Tabletop roleplaying adds maps and figures to show direction and relative positions of individuals and objects. These types of simulations are particularly beneficial when the real events occur infrequently or would be dangerous or costly to simulate with other methods. Versions of these simulations can include attributes for the human characters portrayed in the simulation. Attributes are quantified variables to distinguish differences between individuals, such as differences in size or athletic ability. These attributes can also include cognitive abilities and personality traits. A tabletop roleplaying structure was designed based on knowledge from multiple scientific fields. This structure determines the options and outcomes of actions attempted by characters in the simulated world. Data generated by this tabletop roleplaying structure are closer to data from actual active-shooter events than data from current AI (artificial intelligence) computational models. This is further improved when scientifically based attributes are incorporated. This tabletop roleplaying structure is defined in formulaic ways with quantified variables to be a template for creating more accurate computational models designed to simulate active-shooter events.

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AI	artificial intelligence
CC	concealed carry
comp.	compassion
d6	six-sided die
d20	twenty-sided die
DM	dungeon master
FBI	federal bureau of investigation
GM	game master
GNS	gamist narrative simulationist
HCI	human computer interaction
HTV	hybrid targeted violence
int.	intellect
IQ	intelligent quotient
MMORPG	massively multiple online roleplaying game
MUD	multi user dungeon
NASA	National Aeronautics and Space Administration
out.	outgoing
RO	resource officer
RPG	roleplaying game
SWAT	special weapons and tactics
TTRPG	tabletop roleplaying game

CHAPTER 1: INTRODUCTION

Active-shooter events are situations involving one or more people currently shooting others within a restricted area. Police officers are the ones that address these events when they occur. Active-shooter events are rare and happen at infrequent rates in various and unpredictable locations. No one department is likely to have much experience with an actual active-shooter event but the police must still be prepared in case an event occurs in their location. So police plan and train for active-shooter events with tabletop planning and live-action simulations.

Current tabletop planning is crude and informal. It is done on static tables with static objects. Roleplaying is not used and there is no defined structure to determine the outcomes of actions. Instead, officers' intuition determines outcomes; what they believe would likely happen. This does not incorporate random factors to account for the unexpected and unimagined, yet statistically possible things, that do happen in real world events. Since these aspects are not captured by this type of tabletop planning, it does not match the real world in this way. Therefore, current tabletop planning is limited in the benefits police officers can gain from it (Nikendei, Zeuch, Dieckmann, Roth, Schafer, Volkol, Schellberg, Herzog, & Junger, 2005).

Live-action simulations involve multiple people moving through actual buildings on foot. A combination of actual and simulated equipment is used. This often includes multiple officers arriving in police vehicles in full police gear with modified weapons or ammunition; multiple emergency personnel in their vehicle; and dozens of other participants to play the roles of shooter(s), bystanders, and victims with prosthetic simulated wounds to wear. The modifications to weapons and ammunition ensures actual bullets are not shot but it may still sound, feel, smell, and look like rear gunfire. To run a live-action simulation of an active-shooter event, lots of planning must be done and multiple organizations, both those directly involved and those in the surrounding areas, need to be informed or coordinated. These live-action simulations are valuable and unlike existing tabletop planning, do allow for the unexpected to arise. However they are resource intensive. At best, live-action simulations are done once or twice a year. This prevents frequent training which is desired to keep the police officers' skills sharp (Chung, Nagashima, Espinosa, Berka, & Baker, 2009). Also since these exercises are infrequent, careful selection has to be made when deciding the nature of the active-shooter event to simulate. This includes how many shooters, what types of weapons they have, the location, and strategy used. This limits the variety in types of active-shooter events police officers can train using live-action simulations.

There are computational models for simulating active-shooter events. This allows for multiple and varied simulated events to be conducted. However, it has been shown that computational models produce less accurate results than roleplaying when human interactions are involved (Green, 2002). This is in part because roleplaying is more accurate at simulating human behavior and decision making than pure computational models. For this dissertation, I examined roleplaying to extract benefits it has to offer for improving current computational models simulating active-shooter events.

Roleplaying captures the nuances of face-to-face social interaction. Tabletop roleplaying offers additional benefits by adding the manual manipulation of physical objects. This increases immersion by the participants. It also allows representation of aspects of the simulated world not easily modeled by roleplaying alone such as relative positions of individuals and objects and determining the outcome of attempting physical tasks (Benford, Magerkurth, & Ljungstrand, 2005).

Many tabletop roleplaying games address in much detail combat between individuals and small groups; including physical factors such as timing and distance but also quantified characteristics to distinguish differences between individuals. Some of the same critical factors in active-shooter events.

Most tabletop roleplaying games also include quantified values to define the abilities of the portrayed characters. This enables players to take on roles of characters with abilities distinct from their own. For example, the character may be more attune to certain stimuli and may be able to react quicker or more easily under particular conditions than the player portraying that character. These abilities are used to simulate physical and cognitive capabilities such as a character’s physical strength or how likely they are to succeed at a particular task. They include innate qualities of the character referred to as attributes and learned and trained abilities referred to as skills.

In order for roleplaying to be an effective tool for serious use as a simulation, it must be engaging and match the real world (Greitzer, Kuchar, & Huston, 2007). Games by design are meant to be engaging. Having a tabletop roleplaying game with a structure based on scientific research would also make it more closely match the real world.

Potential abilities for characters in the simulation come from scientific research. Psychology quantifies mental capabilities like IQ and further breaks this down into subcategories. It also defines personality traits. Research in physical education defines and quantifies physical capabilities like strength and flexibility. Cognitive science explains how abilities like attention and memory work. It also defines how individuals acquire and develop mental and physical skills. However, the rules and variables used to quantify the abilities of characters in current roleplaying games is not determined or defined using this knowledge. These fields offer guidance for modeling mental and physical abilities and personality traits of characters in roleplaying simulations. Following this guidance improves tabletop roleplaying's ability to accurately simulation the real world by more closely matching it. This defines a structure that produces data closer to real world data and makes better predictions (Sutcliffe, 2002; Castella, Trung, & Boissau, 2005).

Roleplaying is superior to current computational models involving human interactions (Green, 2002). However, to implement aspects of roleplaying into a computational model there has to be a clearly defined structure with quantified variables and formulaic definitions for how those variables interact with each other and the shared environment and other individuals in the simulation. Roleplaying does not necessarily have these things but most tabletop roleplaying games do have all these things.

A tabletop roleplaying structure with quantified variables and formulaic definitions could be implemented into computational models. The computational models would be improvements over earlier designs by incorporating aspects of roleplaying. The impact of this could affect artificial intelligence design and agent based modeling more broadly (McGrew, 2009).

CHAPTER 2: BACKGROUND

This paper provides a structure for designing better computational models. This structure was formed using a novel method based on tabletop roleplaying. Although targeted at simulations of active-shooter events, there is potential for the structure and the methods used to produce it, to be utilized more broadly. The nature of this novel approach required bringing together vast and varied areas of research, all which lead to the methodology used to define the tabletop roleplaying structure. This consists of relevant research on roleplaying; serious games; a psychological, physical education, and cognitive science basis for quantifying abilities; how technology can be incorporated with tabletop games; the need to improve simulations for better capturing the real world; and planning and training for active-shooter events. Reviews of these areas of research follow, organized into the following sections: roleplaying, serious use, attributes, skills, game mechanics, tabletop technology, simulation training, and active-shooter events.

Gaps in the research is highlighted where these different fields overlap and suggest potential benefits from joining these areas to improve forecast accuracy by applying scientific knowledge to tabletop roleplaying to produce a simulation that more closely matches the real world.

Each section includes related papers on one of the above-mentioned subject matters. The examination of the methods and results of each paper will be from the perspective of how they relate to a tabletop roleplaying simulation tool for active-shooter events.

2.1 Roleplaying

Roleplaying is acting out an assumed role. It has had long use in therapy and as a technique of actors. Roleplaying games (RPGs) involve the participants, called players taking on roles of fictional characters that interact with other fictional characters in a shared imaginary world. Often these games incorporate dice, recorded character statistics, miniature figure representations, and maps. To understand this activity fully it is useful to see the history and changes that took place to other activities over time that led to roleplaying games.

Dating back hundreds of years, military leaders would use models to represent combat units on a miniaturized map of the battlefield for strategic and tactical planning. It is worth noting the original serious simulation purpose. These were models used for testing and planning with the intention to implement in the real world. From this evolved the first tabletop war games, having game rules and points regulate the control of miniature armies. Dice were a common means used to incorporate a degree of uncertainty, as would be the case on real battlefields. Players would control opposing armies adhering to rules for combat and troop movement. They often reenacted historical battles with the possibilities of different outcomes.

Out of this hobby came the first roleplaying game Braunstein® by Major David Wesely in 1967. Instead of players controlling troops and military units, Wesely had each player control a single person in a small town. The concept of controlling a single character was unique at the time. The freedom to do whatever you wanted within your character’s capacity was a major appeal that contrasted with the war gamming restrictions and focus on gaining points. However, the largest shift was the fact that it allowed players to become attached to their characters, identify with them personally, and view the fictional world from the character's perspective.

One of these original role-players was Dave Arneson and he used this concept to modify the war game Chainmail®, created by E. Gary Gygax and Jeff Perren. From there Gygax and Arneson created Dungeons and Dragons® (Waskul & Lust, 2004), the first published roleplaying game in 1974, which is still popular today. Dungeons and Dragons® had a major influence on early Multi User Dungeons (MUDs) computer games. This impact persists in modern computer and tabletop roleplaying games.

Tabletop also known as pen-and-paper, roleplaying games are generally played in person with other people, often sitting at a table together with the other players. The characters are represented on paper by the values of the various abilities used the game. This includes attributes for innate abilities such as height and skills for acquired abilities such as shooting. Dice rolls are usually combined with attributes and skills to determine the outcomes of events. Often models and maps will be used to represent character position in relation to other characters and features in the game world; a carryover from its war gaming roots.

Most tabletop roleplaying games have one participant that is different from the rest. This individual oversees the game and comes up with the scenarios the other players are to engage in. They are referred to differently in different games, Dungeon Master (DM) in Dungeons and Dragons® but Game Master (GM) is the most common. Other common terms are referee and judge. Each of the other participants is a player and usually assumes the role of just one character.

By contrast computer roleplaying games are usually solitary activities or connected with other players through a network. All representations are handled by the computer including internal character qualities like attributes and skills as well as external information such as the character's position in the game world.

There have been formal contrasts and comparisons between tabletop and computer roleplaying games (Tychsen, 2006) and research into the possible future formats they could take (Eyles & Eglin, 2007). There are key differences especially when considering having computational models automate some of the activities done by people in tabletop versions. Ways to make this transition will be addressed.

Many of the conventions used in roleplaying games today have changed little from this hobbyist invention over forty years ago. This influence extends to the choices of character attributes used in roleplaying games. Character attributes are numerically valued qualities that represent the innate abilities of the character. Different games have used various attributes (Bostan & Ogut, 2009) for their characters but most give little or no regard for having a real world or scientific basis. Yet attributes are a core foundation that most other roleplaying game aspects depend upon. This includes skills and other defining characteristics ranging widely from how fast a character can move to their visual acuity. Character attributes are arguably the single most important aspect to a roleplaying game, particularly one focusing on simulating the real world.

In addition to character attributes which are meant to reflect innate ability, skills are used to represent learned abilities and gained knowledge. Similar to attributes, these skills have numerical values to represent level of expertise. However, what constitutes a skill can vary greatly and usually has little to no scientific basis. Even the time required to learn or improve a skill is usually based on arbitrary formulas applied universally to all skills rather than using scientific research to determine the rate of skill development.

There has been an analysis of roleplaying games from the community that is beneficial to this review because it defines categories that distinguish different types of roleplaying games. Some of these categories are better suited for serious game use than others. These categories can be further examined to evaluate their compatibility with having scientific principles applied and used for serious simulation purposes.

GNS theory (Edwards, 2001) as presented by Ron Edwards reflects upon the different types of roleplaying games. Edwards defines three large categories that give the theory its name; Gamist, Narrativist, and Simulationist.

Roleplaying games that fall in the Gamist category put their focus on the rules of the game and competition. Unless the rules are specifically designed for an educational purpose they may be limited in their use as a serious game.

Narrativist games are defined by their focus to the development of a story, internal character struggles, and interpersonal conflicts between personalities in the game. For more socially oriented subject matters, these games may have use a serious use. Cognitive science principles may be particularly applicable when dealing with personality and cognitive differences between individuals. Highlighting such differences could give insight to how others perceive, think, and make decisions.

The third and final category is Simulationist. These games are defined by focusing on simulating a particular situation or scenario. Detail and accuracy are key factors in these games. Although not limited to simulating the real world, this is where this type of game could be used the most for serious game and simulation purposes. In order for this to be achieved better measures and rules based on scientific research will have to be incorporated into such games. Some games in this category already include certain scientific principles. This is usually in regards to physical phenomenon and interactions such as applying physics in combat. However, this could be expanded to include cognitive science to model things like; perception, memory, skill acquisition and mastery, and other mental abilities.

Roleplaying games have their roots in simulation; models used to represent scenarios to be implemented in the real world. Simulations are useful tools for teaching and study. With the implementation of scientific principles, roleplaying games could more accurately simulate the real world. Such a simulation could be used for training or to test theories in a safer and less expensive environment than in the real world. If converted to a computational model, multiple scenarios could quickly be ran.

2.2 Serious Use

Serious games use the engagement of games for purposes other than entertainment. This includes roleplaying designed for serious purposes. The research in this section utilizes roleplaying to improve upon existing practices in various different domains.

Serious games are games with a purpose to instruct, inform, or provide insight (Shute, et al., 2009). The fun aspect of games motivates users to play (Dickey, 2007). This quality can be exploited to assist learning by incorporating educational aspects to an enjoyable game. This has been shown to be effective (D’Aquino, Le Page, Bousquet, & Bah, 2003).

The benefits of using simulations (Sutcliffe, 2002), roleplaying (Castella, Trung, & Boissau, 2005), and games in general for education, training, and study is well established (Ruben, 1999). The benefits of using serious games are numerous (Shute, Ventura, Bauer, & Zapata-Rivera, 2009). Therefore, it is important to create serious roleplaying games in order to expand upon the benefits of both simulations and roleplaying.

Using games to teach offers many benefits by encouraging experimentation and exploration (Squire & Jenkins, 2003). Motivation can be a difficult hurdle for some students and subject matters. Yet individuals will spend hours of their free time playing games (Greitzer, Kuchar, & Huston, 2007). Serious or educational games can bridge this gap. The student learns while having fun.

The advantages to using games to teach include (Schmidt, et al., 1988):

- Appeal – more people will be reached
- Time – more will be spent on the activity
- Effective – better than lecture

For various subject matters roleplaying has been proven a beneficial tool for training, decision making, and forecasting (Green, 2002). When complex human interactions or social issues are involved, purely algorithmic or mathematical models can break down but this is where roleplaying is particularly useful. Research into the use of technologies and games to convey a message or story should incorporate roleplaying because it does these things naturally (Waskul & Lust, 2004a).

Each person involved in a roleplaying session assumes one of the assigned roles and will behave according to the motivations and goals of their character but they will not be given a script or step-by-step directions to follow. This allows the scenario to play out live with each participant reacting to events as they unfold.

This sort of emerging scenario uses human agents to capture the depth and breadth of possible human responses. Part of the value of roleplaying both as entertainment and for training is the seemingly unpredictable or near infinite possible outcomes.

Roleplaying can involve just the human actors, if the sole focus in on human interaction. However, models and props can be utilized to represent objects or environmental conditions to create a more immersed setting. This is often called tabletop roleplaying because the models are usually placed on a table. This may be done when roleplaying is but part of a broader simulation. Not all simulations incorporate roleplaying but those that involve significant levels of complex human interaction will often do so in order to model this behavior.

Nikendei, et al. (2005) included roleplaying in training to create a more realistic training environment for teaching technical medical skills to undergraduate medical students. The goals were to see if this could be implemented and if so, would it be beneficial to the participants and increase the value of medical training.

Nikendei, et al. (2005) tried to get the most benefit out of simulations for undergraduate medical students as part of their regular education by comparing term-one training, which did not include roleplaying to term-two that did. Feedback was gathered from 114 participants in term-one and 79 in term-two that volunteered to fill out evaluation forms at the end of the semester.

The first semester had training sessions without roleplaying. These consisted of two 45-minute sections each on a different technical skill such as administering or using medical equipment. After given instruction, the students performed the tasks (Nikendei, et al., 2005).

Roleplaying was introduced in the next term. The students were placed in groups of three. Each group member had a different role; patient, doctor, or supervisor. Specific instructions and tasks were given to the participants. The stories of each session were based on case studies. Each participant was privately given unique information about their role and they wore appropriate clothing to match. Once started, the roleplaying sessions were not to be interrupted if possible. Students in the role of supervisor had a checklist to mark as they observed. At the end of the session, the supervisor gave feedback to the doctor. Roles were switched so each student could spend time in each role (Nikendei, et al., 2005).

Students in the roleplaying sessions rated their training much more useful, relevant, and engaging compared to the rating students gave the traditional training, which consisted of instruction and performance on a dummy. The roleplaying allowed for natural interactions and situations to unfold and required the use of social skills, which will be an important part of their future professions as medical doctors (Nikendei, et al., 2005).

Evaluations of the training with and without roleplaying were from questionnaires filled out by the students. Comments from the first term students included wanting training to be more realistic, more time to practice with each other, and shorter lectures. The students rated the roleplaying sessions much more valuable than they did any of the other training; 67.5% found the roleplaying improved professionalism and 64.9% thought it improved safety. Most also wanted more roleplaying time to practice their skills (Nikendei, et al., 2005).

The students were willing to engage in roleplaying and found the experience valuable. Of particular importance to them was the feedback at the end of the roleplaying sessions from the supervisor (Nikendei, et al., 2005).

This paper points out the benefits of roleplaying to assist in technical training and makes the point that this can begin early in a student's training. It allows a more realistic and immersive experience yet remains in a safe environment. The risks are only simulated mistakes to simulated patients but because each of the simulated roles is being portrayed by a real person, it can capture a sense of authenticity. Furthermore, playing the role of a patient allows these future doctors to see the situation from their future patients' perspective, gaining insight to bedside manner they might not otherwise get.

Unfortunately there were no objective measures in this study to see if the roleplaying actually improved performance rather than just students' preference for the training although there are known benefits to learning and retention just from increased interest and engagement (Squire & Jenkins, 2003). It would be informative to see the results of such a study with more objective measures.

Poor forecasting can be costly to those that follow its misguided recommendations. Green (2002) presents examples of roleplaying giving more accurate predictions than computational models.

Green (2002) took six different conflicts from the real world. Each involved high stakes and a small number of individuals. These situations included protests, strikes, and market behavior. With each; unaided judgment, roleplaying, and game theorist predictions were made.

For unaided judgment, each participant read the conditions of one of the conflicts. They were asked to predict the outcome from a choice of options. Dozens of college students participated. On average across all conflicts, their predictions were correct 28% of the time (Green, 2002).

For roleplaying, groups of participants were used. Each person was given information on the one role in the conflict they were to role-play. Hundreds of college students participated. On average across all conflicts, their predictions were correct 64% of the time (Green, 2002).

For the game theorists 21 experts in game theory responded after receiving written conditions of the conflicts. On average across all conflicts, their predictions were correct 37% of the time (Green, 2002).

As an example, one of the situations was an energy company monopoly that the government wanted to break up. The results from a roleplaying forecast predicted an outcome that disagreed with what experts in the field believed would happen. They ignored this forecast and turned to game theory. However, the roleplaying forecast gave the best prediction of what actually happened (Green, 2002).

The goal was to compare the accuracy of the three methods in their ability to make predictions. The results from roleplaying were significantly better than the results from unaided judgment and game theory experts (Green, 2002).

Forecasting human behavior is difficult. This is true when dealing with market behavior or outcomes from group interactions. Green (2002) demonstrated that roleplaying forecasting is superior to pure mathematical models when human behavior and decision making is involved. Currently many models do not incorporate roleplaying even though human behavior and decision making is a prevalent factor. For a purely computational model there would have to be a way to quantify these factors.

Green (2002) explains that computational models make assumptions for their agents that do not match real people. Such assumptions include perfect knowledge of the situation, always acting only in one’s own best interest, clear goals that do not change, and uniform perception by all agents.

Roleplaying allows for subtle social interactions, perceptions, and emotional factors that are not simulated accurately by current computational models. Roleplaying also captures biases individuals might have that are difficult to define. Some biases exist based on the role of the individual. Some stem from multiple issues being linked together in the individual’s mind.

Green (2002) clearly demonstrated the benefits of using roleplaying to simulate and predict. Each situation involved high stakes and a small number of individuals as are often the case with active-shooter events.

However, these situations did not involve critical relative locations of individuals and objects as there might be in a military or police operation. The lack of maps and tangible objects to represent these qualities limited the types of conflicts that could be modeled.

In addition, there was not a way to capture cognitive and personality differences between characters being portrayed and the players portraying them. These could be important distinctions for some simulated scenarios. People could perhaps portray a character with less cognitive ability than their own but not someone with greater perception, knowledge, or expertise.

Determining the uncertain outcome of cognitive or physical tasks by the character would be more arbitrary without defined quantified abilities to determine the odds of a particular task being successful or not. For example, the odds of hitting a target depend on the weapon, range, visibility, movement, and other physical factors but also the skill and experience of the shooter.

Many of these things can be addressed by incorporating quantified abilities for the characters being role-played. These come in the form of attributes for innate abilities and skills for abilities acquired through training or learning.

2.3 Attributes

Most tabletop roleplaying games have statistics to represent the abilities of the portrayed characters. This is necessary to define capacities and limits to what characters can do in the simulated world. The distinctions characters have from other characters are modeled with numerically valued ability scores.

However, the abilities used in most games are based on tradition or theories of what players will find fun or interesting (Derenard & Kline, 1990) and not on scientific knowledge. This can begin to be addressed by considering ways to simulate real human abilities.

In roleplaying the innate abilities of a character are the character’s attributes. These attributes include physical abilities such as strength and speed as well as cognitive abilities such as memory and attention. Qualities like personality and psychology are key measures used to define an individual (Bouchard & McGue, 2003) and should be considered in a serious roleplaying simulation. Research in physical performance, psychology, and cognitive science is a guide to defining these characteristics.

Cognitive science has quantified, categorized, and placed many cognitive abilities in hierarchical structures. This is an area well established and backed by extensive research. Cognitive science has been used to define many cognitive abilities including attention, which plays a role in models capturing “in the moment” situations. Often cognitive science turns to neuroscience to inform its theories. The following research describes some of these cognitive abilities and how they relate to each other.

The work by Undheim and Gustafsson (1987) demonstrated how these cognitive abilities are confirmed and placed in relation to one another and how the existing hierarchical structure emerged. They sought to prove that fluid intelligence and the higher-level general intelligence were equivalent. Their paper demonstrates the methods used to evaluate and define the hierarchical structure of quantifiable cognitive abilities.

Intelligence has a well- defined structure that could be examined and incorporated into the simulation structure as either a single attribute or several sub-attributes. General intelligence is a second-level latent variable or tertiary ability that links and impacts lower first-level latent variables also known as secondary abilities or broad level factors which in turn influences primary abilities. Fluid intelligence was a secondary ability that included primary reasoning abilities (Undheim & Gustafsson, 1987).

Undheim & Gustafsson (1987) compared relevance by using three different datasets and two different techniques all of which confirmed the equivalence fluid intelligence, a broad level factor, with general intelligence, a top-level factor (Undheim & Gustafsson, 1987).

Different primary cognitive abilities were tested in earlier work with a group of 1200 16-year-olds. The hierarchy that emerged was tested with linear structural relations on three different data-sets of results from testing groups of 144 11-year-olds, 149 13-year-olds, and 148 15-year-olds. Each group was given different sets of tests but all fell into established categories and tested the same primary abilities. Two different techniques were used on each data-set. The first adjusted a theoretical model to fit the data based on previous work with multiple factor analysis. The second technique aggregated test scores. This meant working from a higher level in the hierarchy and so prevented the second technique from defining primary abilities (Undheim & Gustafsson, 1987).

The individual tests measured primary abilities in varying areas and included object assembly for visualization, card rotations for spatial relations, forward and backward digits for memory span, arithmetic for general reasoning, vocabulary for verbal comprehension, and symbol identities for speed of discrimination (Undheim & Gustafsson, 1987).

These primary factors were then grouped into broad factors including visualization, speed, crystallized intelligence for comprehension tests, and fluid intelligence for reasoning tests. The linear structural relations method was used on the data-sets to identify connections between these primary and secondary abilities and to the highest ability of general intelligence. In all cases, fluid intelligence was shown to be equivalent to general intelligence and so was not needed as a separate broad level factor and could collapse into general intelligence. The other broad factors remained distinct as independent categories in the hierarchy (Undheim & Gustafsson, 1987).

The results from the data sets and techniques all indicated a close connection between general intelligence and fluid intelligence and this relation was closer than any other connections in the hierarchy (Undheim & Gustafsson, 1987).

This meant that fluid intelligence was not a distinct cognitive ability separate form general intelligence. Even though this modified the hierarchy of quantifiable cognitive abilities, the overall structure of three tiers with general intelligence at the top did not change. This was confirmed from testing of every possible combination of data set and technique available (Undheim & Gustafsson, 1987).

In addition to achieving their goal of showing that general intelligence and fluid intelligence were the same, they showed a common hierarchy emerging from all the data sets. This can be seen in the diagrams in their paper showing the hierarchy that emerged from each data set and technique (Undheim & Gustafsson, 1987).

The strength of this work is the breadth of different groups, different tests, and different techniques to create the hierarchy models. It also demonstrates the tight scrutiny that a cognitive ability must withstand to become or remain a distinct ability. The theoretical models had to be adjusted to fit the results. The data is taken and from the research, then the model is created.

This established hierarchy of human cognitive abilities could be used to define the abilities in roleplaying games to create a more accurate simulation. Quantifying these abilities would produce a structure that could be implemented in computational models.

Lubinski (2004) reviewed the history of quantifying and classifying cognitive abilities and highlighted the impact of an individual’s abilities as testable in adolescence can affect the trajectory of their life including areas of education and occupational choices. The paper presented a comprehensive look at all the work done regarding categorizing quantified cognitive abilities and how this work lead to the current hierarchical structure. This structure has been confirmed more than any other aspect of psychology.

There is a consensus that cognitive abilities fit within a defined hierarchy. Just below the top level of general intelligence are mid-level domains of quantitative, spatial, and verbal. The relative differences between these mid-level abilities as well as the general intelligence score have major predictable impacts on an individual's life including educational achievements and occupational choices. These factors can be detected and nurtured at an early age. In particular, about 1% of the general population has a doctorate degree but children scoring in the top 1% in general intelligence tests are 25 times more likely to get a doctorate eventually and those scoring in the top 0.01% are 50 times as likely (Lubinski, 2004).

Widely varying tests measure different aspects of general intelligence. The qualities these tests measure in turn define general intelligence which includes abilities to problem solve, comprehend, reason and learn. Individuals with high general ability scores perform these tasks more easily. Cognitive abilities and in particular general intelligence need to be recognized as having impact beyond just education (Lubinski, 2004).

Lubinski (2004) recognized seminal work in five key areas that helped define cognitive abilities. This included work showing a strong inheritable factor determining general intelligence. Another study followed individuals for 66 years confirming the stability of cognitive abilities from test score results from when they were 11 years old remaining unchanged throughout their lifetime. The other defining works demonstrated the impact of cognitive abilities on different aspects of an individual's life including work, education, and sociology.

Lubinski (2004) stressed the misconception and under appreciation of the work on cognitive abilities, particularly those under general intelligence. They could be more widely used for prediction given an individual's scores in these established abilities.

The established hierarchy consists of three levels with general intelligence alone at the top, which together with the three abilities just below this level of quantitative, verbal, and spatial make up the significance in abilities that distinguish individuals (Lubinski, 2004).

Historic errors occurred through the years leading to today's established structure. These included having tests for distinct defined areas that turned out to be just different names for the same ability (Lubinski, 2004). This is to be avoided but can be discovered with analysis that shows the correlation between abilities as in Undheim and Gustafsson (1987). Also tests used to distinguish qualities such as achievement and aptitude have been shown to not be distinct, only varying degrees of established abilities. To identify bias, tests are categorized based on sample size, link to a particular program, how soon testing occurs after learning, and whether the goal of assessment is to measure current ability or to predict potential (Lubinski, 2004).

It can be difficult to isolate testing for a specific cognitive task because general intelligence factors into all problem solving. However, this is not even desired. It is best to have multiple tests that cover varying abilities while each still also tests the desired ability to measure. This allows competition between factors with the one in common emerging (Lubinski, 2004).

The variance between individuals consists of 50% from general intelligence and as much as 11% from each of the mid-level abilities. Due to overlapping of tested abilities, about 85% of general intelligence can be accounted for by aggregating scores form these four areas (Lubinski, 2004).

Additions to the general intelligence hierarchy such as measures for emotion or morals have been made but they were not substantive. Any attempt to add to or change the established structure must prove to be actually measurably different from any existing ability (Lubinski, 2004).

It can be difficult to separate general intelligence from socioeconomic status to determine which has more of an impact on the other. One study reviewed by Lubinski (2004) attempted to isolate the two by conducting a study on siblings that were raised together with one having an IQ within a 25th and 74th percentile and the other sibling outside of this range either higher or lower. Then they were tracked over 15 years to determine their achieved socioeconomic status as adults. Since they were raised together they started off with the same socioeconomic status so the distinguishing factor between them would be difference in IQ which is a measure of general intelligence. The study included 1,074 pairs of siblings. There was significant difference in sibling outcomes in education and employment. The outcome discrepancies between individuals of the same IQ but different socioeconomic background were much less significant thus showing the greater impact of general intelligence (Lubinski, 2004). The work of Spinath, Ronald, Harlaar, Price, & Plomin, (2003) with children and twins also provides strong genetic support of a general intelligence factor for wide reaching cognitive abilities.

Cognitive abilities are ordered hierarchically with the root being general intelligence which is a broad and deep ability to learn, comprehend, plan, reason, and problem solve. It is the single most important determinate of how an individual will perform at a particular task as well as succeed at general measurable areas of life. This general intelligence is Stratum III in a three Stratum model (Lubinski, 2004). Cognitive attributes below this root are Stratum II cognitive abilities. Each of these Stratum II abilities may contain narrower Stratum I abilities, many which need further research to better evaluate their place in the hierarchy (McGrew, 2009).

This is an excellent place to start for creating cognitive science based attributes for a roleplaying game. The model would have a general intelligence attribute with different levels of sub-attributes. These sub-attributes would be relative to the larger Stratum to which they belong and ultimately relative to general intelligence. For easy of record keeping these sub-attributes only need to be recorded if they deviate above or below the larger Stratum to which they belong.

Therefore having a high score in general intelligence means a character is good at all cognitive abilities. Since general intelligence accounts for about half of measurable variance (Harden, Turkheimer, & Loehlin, 2006) the allowable variance of the Stratum II and Stratum I abilities combined should not be greater than that allowed for general intelligence. For example if the maximum range of variance in a population on any cognitive measure is ±6 then general intelligence scores should be allowed to vary by ±3 and no combination of a Stratum II with any of its child Stratum I sub-attributes should be allowed to vary more than ±3, with general intelligence accounting for the other ±3.

Any sub-attribute shown to have less than a total ±6 variance should have an equally reduced variance.

Based on the list of Stratum II or broad abilities, these sub-attributes under general intelligence would include; fluid reasoning, short-term memory, kinesthetic abilities, psychomotor abilities, psychomotor speed, cognitive processing speed, decision and reaction speed, visual processing, tactile abilities, olfactory abilities, reading and writing, long-term storage and retrieval, quantitative knowledge, comprehension-knowledge, and general domain-specific knowledge (Bouchard & McGue, 2003). Given the importance of attributes in a serious tabletop roleplaying simulation it is prudent to consider each of the sub-attributes and how they might impact the simulation.

Reasoning refers to problem solving abilities when dealing with new problems that are not solvable without controlled and deliberate effort. High scores reduce the time it takes to solve problems and allows more complex problems to be solved. Narrower sub-attributes include; applied-math, applied-reason, deduction, induction, and reason-speed (McGrew, 2009).

Quantitative knowledge refers to the ability to gain and access math skills. High scores make it easier to learn and retain but not utilize math skills. Reason is used for application (McGrew, 2009).

Comprehension represents the ability to gain, access, and utilize information gained. High scores increase the speed at which a character can gain, access, and utilize linguistic and cultural information as well as be a bonus to performing or observing verbal based activities. Narrower sub-attributes include; commune, cultural-info, grammar, lexicon, listen, multilingual, oration, and verbal-info (McGrew, 2009).

Literary represents the ability to gain, access, and utilize reading and writing skills. High scores decrease literary errors and increase literary comprehension and speed. Narrower sub-attributes include; reading-comprehension, spelling-ability, and writing-aptitude (McGrew, 2009).

Domain-learning refers to the ability to gain and access deep knowledge of a subject. High scores make it easier to learn and retain but not utilize domain skills, as exemplified by the narrower sub-attributes. Reason is used for application. Narrower sub-attributes vary greatly over a wide range of subjects and include; behavioral-content, geographical, mechanical, scientific, and many other specialized areas knowledge (McGrew, 2009).

Working-Memory has been shown to be the best model of immediate memory (Bermudez, 2010). This refers to mental representations that are immediately available without the need for effort but it is limited in both capacity and duration, which is quite brief. It has two separate capacities the phonological loop and the visuospatial scratchpad, with suggestions of additional ones (O'Reilly, Braver, & Cohen, 1997). Each works independent of the other. The phonological loop is for language information and the visuospatial scratchpad is for items with visual meaning.

Working memory also consists of a central executive, which has attention like qualities. This could connect abilities previous seen as separate into a single model (Fernandez-Duque, Baird, & Posner, 2000). Working memory is about controlling attention and keeping information in an active and quickly retrievable state. Without any distracting cues, items can be remembered much longer and individuals with high working memory capacities are less affected by interference. Working memory is a quality that reaches across many intellectual abilities (Kane & Engle, 2002; Engle, 2002; Undheim & Gustafsson, 1987). High scores in working-memory mean a larger capacity and shorter retrieval time. Narrower sub-attributes are; central-executive, visuospatial-sketchpad, and phonological-loop.

From here information can be encoded in long-term memory. The amount of attention and effort paid during this process determines the quality of the memory and the ease of retrieval.

Long-term memory describes the abilities to store, consolidate, and retrieve memories storied for a few minutes or longer. It can be broken down into categories by the types of knowledge. The largest of these divisions are declarative and non-declarative memory (McGrew, 2009).

Declarative memory includes facts and events we have explicit access to. We can pull these to mind and talk about or reflect upon them. The ease to which we can recall information depends in part on how closely related it is to the information we are currently thinking about. This relation is unique to the individual and depends on the context the information was learned. The total of all such relations form a network (McGrew, 2009).

Non-declarative memory refers to everything else. Of particular interest here are the procedural skills because of the tie in to an examination of skill acquisition and mastery. Procedural skills can be called upon and performed by experienced practitioners. The ease to which this is done depends on the level of expertise, as we will see expertise and mastery are defined as being able to call upon these skills automatically. However, when pressed to explain how such performances are done, the practitioner often finds it difficult if not impossible to express adequately their thought process. In fact studies have shown that when asked to reflect back on their own thought processes; experts will unwittingly give false explanations as to how or why they produced their performance (Lipford, Stukes, Dou, Hawkins, & Chang, 2010).

High scores in long-term memory allow for better connections between memories, more creative ideas, and better retention from study. Narrower sub-attributes include; association, creativity, expression, figure-memory, free-recall, learning, meaningful-memory, name-facility, and word-fluency (McGrew, 2009).

Processing speed refers to the performance of simple tasks. High scores reduce the time it takes to perform these tasks. Narrower sub-attributes include; number-facility, perception-quickness, reading-speed, reason-quickness, and writing-speed (McGrew, 2009).

Reaction refers to making simple decisions when stimulated. High scores reduce the time it takes to make these decisions. Narrower sub-attributes include; choice-reaction, compare-reaction, comprehend-reaction, inspect-reaction, and simple-reaction (McGrew, 2009).

Kinesthetic represents a connection between the body and the senses and refers to the perception of one’s own bodily position and movement. High scores allow for more graceful and precise movements. This includes not only gross motor movements like walking but also more subtle movements like talking, gesturing, and making facial expressions (McGrew, 2009).

Psychomotor refers to the performance of voluntary physical body movements. High scores allow for more precise, coordinated, or powerful movements. Narrower sub-attributes include; aim, applied-strength, athleticism, balance, manual, precision, and steadiness (McGrew, 2009).

Speed refers to the performance of rapid and fluent physical movements that are mostly independent of conscious control. High scores reduce the time it takes to perform these tasks and allows for greater fluency when doing so. Narrower sub-attributes include; articulation-speed, limb-speed, move-time, and writing-speed (McGrew, 2009).

The above list is derived from different methods of categorizing cognitive abilities but is certainly not the only way they can be organized. The list should be scrutinized to ensure it best reflects and models the intended cognitive abilities (Sternberg, 1999). Several alternatives and clarifications that relate to the above model are listed below.

Different models combine comprehension and literary (Undheim & Gustafsson, 1987) as well as psychomotor and speed. Perhaps these pairings could be represented with a compromise by having an attribute the pair uniquely belongs under that is between Stratum III and Stratum II.

Long-term memory has connections with creativity as well as language that could be represented differently. Creativity is listed as a sub-attribute of long-term memory but it may have other independent factors as well. Connections with language could be represented by having appropriate language based Stratum I sub-attributes be relative to both long-term memory and their listed parent Stratum II attribute.

Different hierarchies (Neisser, et al., 1996) place reason, comprehension, visual, and processing speed under general intelligence with the other Stratum II abilities under them.

Some of the Stratum I sub-attributes overlap with other Stratum I abilities under different Stratum II attributes. Such cases can be handled in one of three ways; distinctions between the two could be made, one of the Stratum I sub-attributes could be dropped from the model, or the two Stratum I sub-attributes could be combined and be relative to both the two Stratum II attributes it falls under. Further research would clarify which approach to take.

The list of Stratum I sub-attributes is not exhaustive. New research could unveil more that could be added to the list. The model is meant to be flexible and allow for these kinds of additions. Likewise some items could be altered or removed from the list if further evidence shows them to behave differently or no longer be distinct.

Some models state processing speed and working memory are not under general intelligence but rather general intelligence is a product of these two factors. This discovery has led to better understanding of the logarithmic and exponential relations common in cognitive abilities (Lubinski, 2004).

The established cognitive hierarchy for humans has been suggested to work for animals as well because they display differences in cognitive abilities among individuals within a species. This has been deemed plausible to apply to apes (Lubinski, 2004).

Relative differences in the different cognitive abilities have an impact on individuals’ lives. This includes education, occupation, socioeconomic status, delinquency, and creativity. It is possible to evaluate these cognitive abilities at an early age. Doing so allows for nurturing particular strengths and predicting likely later life choices and outcomes (Lubinski, 2004).

One study focused on children scoring in the top 3% on general intelligence tests and grouped them based on their relative scores in the mid-level abilities. At age 18, they were asked their most and least favorite subjects in school. At age 23, their college major was recorded, and at age 33, their occupation was recorded. Individuals that scored higher in quantitative than verbal ability disliked humanities and liked math and science; majored in math, engineering or science in college; and got careers in those areas. The opposite was true for individuals that scored higher in verbal than quantitative ability (Lubinski, 2004).

School and career was also affected by spatial scores but these corresponded somewhat with quantitative ability. There were distinctions in that individuals with high spatial ability were more likely to go into engineering or science than mathematics. However, Lubinski (2004) pointed out that spatial ability is often not tested but is a valuable aspect for determining one's potential and likely education and career choices. Distinctions in cognitive abilities are comparable to body types for athletes of different sports where different profiles are better suited for specific activities. By not testing for spatial ability specifically about half of the people in the top 1% are not detected (Lubinski, 2004).

Lubinski (2004) stated including factors outside of cognitive abilities such as personality and interests would give assessments and predictions that are even more accurate. These are measured using different dimensions for each quality. Another factor in career success separate from these cognitive abilities is determination and persistence. Incorporating all the factors mentioned will create a better model of human behavior

(Lubinski, 2004). These factors could be incorporated into a roleplaying simulation to better define and predict the behavior and actions of portrayed characters.

Zillig, Pytlik, Hemenover, and Dienstbier (2002) explain the Big 5 personality traits and how these emerged from extensive research. These could be incorporated to define characters portrayed in a simulation to better guide motivation and decision-making.

For the senses, visual, auditory, tactile, and olfactory processing do fit in the cognitive hierarchy (McGrew, 2009). Areas in the brain map onto locations on the skin for touch or locations in the visual field for vision. Perhaps there is similar mapping for memory but this may not be as simple as being based on a timeline or geographical locations. This map may be more of a network of related conceptual nodes. Both types can be represented by a network. A geographical map can be seen as a specific type of network. However, the senses also all dependent on physical qualities of the senses like the physical qualities of the eye.

Perception is often viewed as a collection of the five senses; vision, hearing, smell, taste, and touch. Each of these senses has multiple properties and features with different measures. Quantifying these qualities is useful for a serious tabletop roleplaying structure and will allow for comparisons and finding common ground.

Visual processing is creating, storing, retrieving and utilizing visual images as well as the spatial orientation of objects. High scores reduce the time it takes to process visual images and allows processing of more complex images. Narrower sub-attributes include; length-estimation, spatial-relation, visual-alterations, visual-memory, and visual-scanning (McGrew, 2009).

One parameter for vision is acuity, the ability to discriminate visual details (Chaudhuri, 2011).The ideal range for brightness to include in one display for maximum discrimination has been found to be about 4 log units of luminance (Kunkel & Reinhard, 2010). The fact acuity drops off outside the area of central focus should be taken into account (Guenter, Finch, Drucker, Tan, & Snyder, 2012). A difference has been found between static or stationary acuity and dynamic acuity which involves movement (Lewis, Rosen, Unsbo, & Gustafsson, 2011). Time of exposure to the stimulus is also a factor when measuring visual acuity (Janabi-Sharifi & Vakanski, 2011). There are temporal factors involved with the detection of stimuli of different intensities of brightness (Rieiro, Martinez-Conde, Danielson, Pardo-Vazquez, Srivastava, & Macknik, 2012). On top of all these variables, age related decline is another factor that must be taken into account (Loughman, Akkali, Beatty, Scanlon, Davison, O'Dwyer, Cantwell, Major, Stack, & Nolan, 2010).

Measurements of stimulus response and their relation to sensation and perception are backed by brain imaging. Different primed visual tasks have been found to use one hemisphere of the brain more than the other (Stevens, Kahn, Wig, & Schacter, 2010). Different types of pattern matching have been linked to different locations in the visual cortex (Tong, Harrison, Dewey, & Kamitani, 2012).

Auditory processing is the handling of auditory information. High scores reduce the time it takes to process sounds and allows for finer distinctions between sounds, and finer location of sound origins. Narrower sub-attributes include; distortion-resistance, frequency-discrimination, hearing-thresholds, intensity-discrimination, music-discrimination, pitch-discrimination, rhythm, sound-location, sound-memory, speech-discrimination, and temporal-tracking (McGrew, 2009).

For hearing, loudness is an obvious parameter but rhythm is another perceptual parameter that has been well documented with equation representation (Oppenheim & Magnasco, 2013). Exposure to noise or loud sounds has a significant impact on our just noticeable thresholds after only a few years (Serra, Biassoni, Richter, Minoldo, Franco, Abraham, Carignani, Joekes, & Yacci, 2005).

Olfactory is the processing of smelled sensations. High scores allow for a more discerning sense of smell and better olfactory memory. Narrower sub-attributes include; olfactory-memory and olfactory-sensitivity (McGrew, 2009).

The sense of smell is commonly measured in detectable parts per million of a specific substance. Emotional state impacts the ability to sense odors and must be taken into account when measuring or modeling olfactory perception (Sugawara, Sugimoto, Minabe, Iura, Okazaki, Nakagawa, Seto, Maruyama, Hirano, & Kitayama, 2009).

The sense of taste may be one of the more primitive senses but there are new ways to look at and measure this sense. An artificial sensor that measured electric potential of milk was able to determine if milk was fresh or spoiled with comparable accuracy to human subjects (Sim, Shya, Ahmad, Shakaff, Othman, & Hitam, 2003). This might mean electric potential is another and more precise way to quantify the gustatory sense.

Another quantifiable measure of gustatory stimuli is the activation of pathways that impact appetite which have been captured with brain scans (Frank, Kaye, Carter, Brooks, May, Fissell, & Stenger, 2003). This can be a way to tie taste and aspects of touch.

Tactile is the processing of touch sensations. High scores allow for finer judgments of temperature and touch (McGrew, 2009). Pain, temperature, pressure, and more all fall under the sense of touch. Like the other senses, age related decline is a factor; tactile-acuity thresholds more than double with age (Dinse, Kleibel, Kalisch, Ragert, Wilimzig, & Tegenthoff, 2006).

Children with movement disorders had a decrease in the ability to discriminate between object sizes as would be expected but also had a diminished ability to determine orientation (Gori, Tinelli, Sandini, Cioni, & Burr, 2012). A similar finding with visually impaired children found they had problems primarily with orientation but also with size discrimination (Gori, Sandini, Martinoli, & Burr, 2010). This research demonstrates the importance of the integration of all our senses that make up perception. There have even been links made between some perceptual abilities, like visual acuity, and IQ (Birch, Garfield, Castaneda, Hughbanks-Wheaton, Uauy, & Hoffman, 2007).

There are underlying principles that span across the sense modalities. Stevens showed that a power function could describe the relation between stimulus intensity and perceptual intensity. The differences were in the exponent values of each of the sense modalities (Stevens, 1957). To model perception, stimulus intensity is best done by the mathematic equation of raising the stimulus intensity to a power that will vary based on the sensory modality. This is multiplied by another variable particular to the sensory modality.

Physical characteristics also need considering. Mital and Kumar (1998) define human strength and lifting ability at various angles and positions. They define norms and deviations. These qualities could be used in part to define physical abilities of characters in a simulation. This could in turn be used to determine the outcome of attempting physical tasks.

These are some of the areas and ways to define and quantify innate human abilities based on scientific research. These are guidelines to defining attributes for a tabletop roleplaying structure for simulating the real world including active-shooter events.

2.4 Skills

In addition to a character's attributes for innate abilities there are also acquired abilities gained through learning and training. In tabletop roleplaying these are referred to as a character's skills.

First the novice level cognitive stage is a functional level in which the individual memorizes domain relevant declarative information. Performers in this stage focus on avoiding big mistakes. This can be achieved in less than fifty hour of training. It is an acceptable level of performance for most simple tasks such as driving, typing, and playing a sport (Ericsson, 2006).

Next is the intermediate level associative stage where the individual develops a procedure for performing the skill. This requires less attention to perform the skill and less noticeable mistakes are made (Ericsson, 2006).

Third is the expert level autonomous stage where the procedure becomes automatic and can be performed more quickly. The performer does not have to exert conscious effort to perform the skill. Drawbacks to this stage include a loss of control because responses become automated and thus can be difficult to adjust. This is also the stage where performance usually plateaus (Ericsson, 2006).

Expertise is often associated with years of experience, the opinions of others in the field, and qualifications such as titles and degrees. However, these criteria do not always correlate with measurable performance. The expectation is that the performance of an expert is reliable and can be trusted to deliver desired results. It is important to quantify expertise based on repeatable performance.

Therefore an expert is defined as a trained individual possessing considerable experience that receives respect from others in their field and is able to produce reliable results, deal adequately with difficult situations, and display knowledge in specialty sub-categories (Hoffman, 1996). Attempts to define expertise based on measured results, has produced equations and numerical values that relate time spent in training to performance (Baker & Cote, 2003).

The definition of an expert in a particular domain is not constant across time. Better training techniques get developed. Old levels of expertise can be achieved quicker. This can be exemplified with athletic performance. Records get broken, usually by a single exceptional individual, and then the techniques of that individual get adopted by others. This can be more difficult to measure in some domains, like baseball, where both the pitchers and batters improve in performance. Even in domains without technical development there are increases in performance over time.

It is relevant to distinguish differences in academic achievement and job performance. Generally academic achievement tests the entire universe of the studied domain. Everything covered in the subject is tested. On the other hand, job performance domains are often ill defined. Evaluations for job performance usually do not test all aspects of the job. Most jobs cover many domains and only a sample are defined and measured. Those tested may not even be frequently used but may still be critical benchmark skills necessary to the job (Ericsson, 2006).

Work in this area has shown that skills must be defined in specific ways to facilitate measurement and this is done more easily for some domains than others (Wijns, Boschetti, & Moresi, 2003). Often, a domain will encompass many different tasks and each will need to be measured separately (Ericsson, 2006).

Although the exact success rates of experts and the ratios of expert performance compared to novice performance will vary by domain, if performance based numerical standards can be established, then comparisons can be made between experts within the same domain. From this, patterns have been found that reach across multiple domains ranging from typing to athletics (Beilock, 2009).

Devising a means to measure performance may be more difficult for some domains than others. For typing, speed and the number of errors can be recorded. Many athletic events inherently have measures such as time and distance as part of the activity. On the other hand for some activities, it may not be apparent at first how to quantify performance. It is important to find a way to quantify the performance in order to objectively define expertise. Many domains actually consist of many subtasks, some of which may lend themselves to objective measurement more than others. Each such subtask may need to be measured separately then brought together to give a full picture of the individual's performance. From this, specific shortcomings may be highlighted and become the focus of targeted training to improve overall performance that was held back by a single or few deficiencies.

When measuring performance, a broad range of difficulties should be tested because there may not be significant difference between experts and novices for low level tasks under ideal conditions (Chung, Nagashima, Espinosa, Berka, & Baker, 2009). The distinction between expert and novice is greatest with difficult tasks, under adverse conditions, and when forced to multitask or deal with time constraints.

The increase in performance when plotted against time spent training follows the power rule (Dehaene, 2003). See power rule Equation 1:

$$T = X + AP^{-b} \tag{1}$$

The specific ratios vary by domain (Johnson, Bellman, & Lohse, 2003). The power rule also applies to the acquisition of motor skills (Newell, 1991). This means for every multiple of time in training there will be some set multiple increase in performance. T is the time required to perform the task. X is the asymptotic speed or minimum time to perform the task even with infinite practice. P is the amount of practice. The values of A and b depend on the skill but b is usually between 0 and 1. This shows that it can be easy to develop lower levels of a skill but this progression will slow with more practice.

A reference point for matching the amount of training to skill competency is given by:

"It requires at least 100 hours of learning and practice to acquire any significant cognitive skill to a reasonable degree of proficiency." (Anderson, 1982).

Expertise is gained over time and requires over 10,000 hours and 10 years of experience. This is a long standing value that generally holds true across domains with some variation on the exact number of hours and years (Lehmann & Ericsson, 1997). As a comparison, tens of thousands of hours are required for a person to learn their native language (Anderson, 1982). Musical instruments can take 20 to 30 years to become an expert whereas memory expertise for memorizing random numbers can be achieved in less than two years.

However, these numbers are not always so clear cut. Having an amount of experience does not ensure the individual will become an expert. Not all experience is equal. The type and quality of the practice also matters. Specifically performance is only improved by time spent in deliberate practice.

Deliberate practice is defined as activities requiring effort and attention devoted to improving skill performance. The degree of effort and attention required to count as deliberate practice excludes activities that are routine or done for entertainment. The boundaries of current performance levels must be pushed (Plant, Ericsson, Hill, & Asberg, 2005).

Tracking deliberate practice predicts achievement in school at all levels. Deliberate practice is necessary to maintain expert level performance. Time spent in deliberate practice, not any other type of experience, corresponds directly with and is the best predictor of performance. Not all domain experience counts as deliberate practice. Most jobs devote less than half their time to deliberate practice (Ericsson, 2006).

Motivation is also a factor for determining the rate at which skills are learned and developed (Kanfer & Ackerman, 1989). It is critical for maintaining the regular deliberate practice necessary to obtain and maintain expertise level performance (Ericsson, 2006).

The focus required for deliberate practice is demanding and can only be maintained for two to four hours per day (Ericsson, 2002). This fits with the 10,000 hours over ten years, which works out to approximately 2.7 hours of training per day. This level of daily practice is necessary to improve performance and must be maintained on a consistent basis with training every day. Less time is necessary to just maintain current levels of expertise.

The maximum amount of daily deliberate practice varies by domain. In particular physically demanding activities may have lower limits. Exceeding the daily limit, for any domain, does not improve performance and can lead to injuries and burnout (Baker, Cote, & Deakin, 2005). The preferred time of day to practice varies by domain as well. Generally mental domains are preferred earlier in the day and physical domains latter in the day.

The expert and novice take different approaches to training. The novice follows instructed activities for maximal gains and this may include awkward self-guided activities. The expert engages in deliberate practice that is maintained over extended amounts of time; years. Deliberate practice is required to push the limits of their performance (Keith & Ericsson, 2007).

Experts spend more time in deliberate practice, on average 3 ½ hours per day, than casual practitioners which spend 1 ½ hours per day on average. Experts also get more sleep, 8 ½ hours on average. Casual practitioners usually get less than 8 hours of sleep. Experts also spend less time on leisure activities (George, Dixon, Stansal, Gelb, & Pheri, 2008).

Experts are able to maintain more complex mental representations (Hmelo-Silver & Pfeffer, 2004). These representations mediate performance and provide a means to gradually increase performance. They control planning, analysis, execution, and monitoring. The use of these representations requires deliberate practice which has a directed goal and is dependent on target performance (Ericsson, 2004).

Chess experts have certain qualities that apply across domains. When they first look at a chess board they make a quick impression and pull applicable moves from memory. Next they evaluate these moves and plan the consequences of their options. At this point even masters will continue to find better moves and therefore continue to improve their performance. The moves must be stored in working memory for flexible evaluation. The manipulation of long-term memory representations develops slowly with chess skill. The more skill the individual has the more effective their representations and the more thorough their plans. Chess experts have much better memory for real chess position but do not do any better than novices at remembering random positions (Reingold, Charness, Pomplun, & Stampe, 2001). Finally experts study masters to evaluate the choices they made so they in turn will be able to make better representations themselves.

Typing is a simple task but there is a large variation in speed between novices and experts. Fast typists look ahead and prepare for future keys. Their fingers will begin moving toward the next keys before the current one is struck. Their speed is greatly reduced if they are not able to look ahead (Keith & Ericsson, 2007).

A typist can increase their speed if full attention is paid to improving speed, typing 10% to 20% faster than normal. This is strenuous and can only be maintain for 15 to 30 minutes per day (Ericsson, 2006). The benefits of this training include being able to look further ahead and recognizing slow key combinations which can be improved with repetition.

Performance speed is found in typing but applies across many domains. Speed depends on cognitive representations (Ericsson, 2006). Anticipation is the key. Predictive cues are perceived, such as the rotation of the hips for a tennis swing. Latter cues are used to update or confirm earlier predictions.

Deliberate practice is task specific. The training can be either solitary or done in groups depending on the nature of the task. Real events are handled more effectively if the same events under the same conditions are done in practiced simulation.

Deliberate practice does not include indirect learning, such as observation. Routine tasks or activities done for fun or stress release do not count as deliberate practice. They can only reinforce current levels of performance. These activities do not modify the task, which is another requirement of deliberate practice.

Deliberate practice follows a specific progression. The focus will be on a specific detail to improve. This will lead to the next stable state in a series. Each state will push slightly beyond the current comfortable bounds but will be achievable within a few hours of training (Ericsson, 2002).

The structure of a designed training regimen will be the same for all in the same domain but the specifics will vary between individuals where training must constantly change with the continuous search for new optimal training. Feedback is essential. This will initially come from the instructor but eventually be self-regulated. During deliberate practice, there will be no decrease in skill performance (Ericsson, 2006).

There will even be cognitive changes to how the brain controls performance. The brain is even more adaptable than once thought. Training actually produces changes in cortical mapping (Puttemans, Wenderoth, & Swinnen, 2005).

It is not the focus of this paper to delve into the neural structures involved in these cognitive processes but it is important to indicate that these models are not purely abstract. Neural imaging evidence indicates that during the perception of motor tasks, different brain regions activate when a subject passively observes someone performing a manual task as opposed to when they will have to imitate what they observe. For the latter many of the same areas light up that are active when the subject actually performs the task. This may be neurological evidence connecting attention and perception. Similar examples for memory, comparing passive observation to actively attempting to store information, may offer additional evidence for connecting these cognitive abilities and the role of attention (Downing, Liu, & Kanwisher, 2001).

Cognitive testing of twins show that cognitive abilities have a strong hereditary factor (Spinath, Ronald, Harlaar, Price, and Plomin, 2003; Harden, Turkheimer, & Loehlin, 2006). However, this does not account for all the variances between individuals and some cognitive abilities appear more influenced by genetics than others (Snyderman & Rothman, 1987). This raises the question, “Which abilities are innate and which are learned?” The answer may not always be clear. Abilities that require deliberate practice to develop expertise clearly have a skill component (Ericsson, Krampe, & Tesch-Romer, 1993).

However, even animals develop abilities through non-associative learning (Kirchkamp, 2012). Since these behaviors and abilities are learned, they too would be classified as skills. Yet some abilities many not be clearly defined as attribute or skill. As with every other aspect of this model, guidance should be taken from research to make the final determination. The best solution may involve a compromise by having both a sub-attribute and a skill to represent a particular observed ability.

Innate ability is a factor however; talent alone does not lead to expertise. Hard work is still necessary. The original view was that aptitude acted as a cap to the degree of skill an individual could achieve (Ericsson, 2006). Regular progress was still determined by training and experience but a point would be reached where the individual could go no further. This was determined by their aptitude.

Most differences in skill level between individuals is tied to time spent in deliberate practice rather than innate ability alone. The amount of daily and annual deliberate practice are the primary differences in individual performance, although other factors contribute. The decrease of time spent in deliberate practice may even explain age related decline (Ward, Hodges, Williams, & Starkes, 2004).

Now it is known that various experiences affect performance. This includes emotional and activity levels. In fact aptitude may primarily consist of the ability to spend more time on deliberate practice (Plant, et al., 2005).

However, this does not mean innate ability has no direct impact on performance. For example, high school basketball students over seven feet tall were able to reach expert level performance in only 6 years. Obviously, some physical and even mental qualities and gifts will have an impact on performance but research suggests that too much emphasis has been placed on these factors (Ericsson, 2006).

Usually when skill is discussed, the references are made to the domain specific skills. However, there are support skills that will assist in obtaining expertise across multiple, even seemingly unrelated domains. These domain general skills accelerate learning, improve performance, apply across many domains, and can be learned. They can be considered life-skills. These skills may be even more important than the domain specific skills for some tasks. These skills include general problem solving techniques and mental skills which include goal setting; mental imagery and rehearsal; relaxation techniques; self-talk management; and planning, preparing and organizing. The benefits of having developed mental skills include sustained confidence, maintain motivation, better stress management, focused attention, and better organized use of time, energy and environment. These mental skills connect to learning and performance.

The broad reach and universal application of these skills is a link to innate abilities covered under attributes (Eccles & Feltovich, 2008). Some attributes may be closely tied to a few or even a single skill yet they still only represent innate ability and the capacity to develop skills.

The focus of most educational institutions and training regimens is on domain specific skills. These are skills that apply to their domain; improving efficiency and effectiveness but have limited use in other domains (Eccles & Feltovich, 2008).

There are different types of domain general skills. The first is weak methods. These are domain independent ways to solve problems. This includes simple algorithms like trial and error, and means-ends analysis. This latter algorithm involves comparing the current state to the target and making a choice to reduce this distance.

The second type is meta-cognition. This is thinking about thinking. It involves higher order thinking. Evaluating, adapting, and monitoring of all types, including emotions, are part of meta-cognition.

The third type is mental skills. This is a more recently defined type of domain general skill that supports learning and performance (Eccles & Feltovich, 2008). Mental skills are made up of several aspects. The first is mental imagery and rehearsal. This includes visualization, a technique often used by athletes to see their performance in their mind's eye and in this way go through the performance over and over again in their mind. Self-talk management is another aspect that involves stopping negative thoughts and self-cueing their attention.

The aspect of goal setting is actually not externally based. It is important to set goals based on variables within the practitioner's control. These goals should push the limits of performance but be reachable. Both of these properties lower stress. This leads to the next aspect, relaxation. This including meditation, which also reduces stress.

Finally there is planning, preparing, and organizing both time and energy. This applies to the environment as well, such as setting up proper study conditions. Managing sleep and the daily limit of deliberate practice also falls under this aspect of domain general skills.

The benefits of developing mental skills are many, including sustained confidence and the ability to maintain motivation and focus attention, both critical for expert levels of deliberate practice. However, mental skills are seen as simple and are rarely formally taught by educators (Smith, 2002).

Studying domain general skills may lead to better understanding of transfer which is the carryover of skill from one domain to another (Blume, et al., 2010). Transfer may stem from application of the same support skills used in different domains.

Early theories of transfer included the concept of identical elements, which explains transfer across domains resulting from shared similar elements. Another early concept is that of natural performers, individuals that happen to have innate talents in both domains. Both of these explanations are limited when compared to all the observed transfer. Perhaps support skills like mental skills will offer new theories to explain transfer (Eccles & Feltovich, 2008).

After training, most performers plateau at an adequate level. This occurs after months or years as a professional under supervision. Such individuals are able to work independently and maintain this level of performance thereafter. Therefore time is only a weak indicator of performance beyond two years (Plant, et al., 2005).

However, beyond achieving expertise levels of skill there are individuals that are able to exceed to exceptional level performance. These individuals continue to improve their performance when others plateau. They are able to find ways to remain in the cognitive stage by focusing on nuances of their performance; such as learning ballet to improve performance on the football field by improving grace. Training in one domain can relate to or benefit performance in another domain. In this example, ballet only counts as deliberate practice for football if it is learned for the purposes of improving football performance. Skills can be represented in different ways, depending on the goal.

Commonalities among exceptional individuals, across domains are the progressions they go through in their domain (Hoffman, 1996). First the activity is introduced as fun, usually when they are a child. During this phase no emphasis is placed on performance, the activity is done simply for enjoyment. Then once potential is recognized formal instruction begins. This requires family support.

Both ordinary experts and exceptional individuals spend nearly equal amounts of time on domain related activities. However, exceptional individuals spend less time on leisure or routine activities and much more on deliberate practice (George, et al., 2008). Again it is the amount of deliberate practice that is the determining factor for performance quality. Knowing when this training began also enables the prediction of when peak performance will occur during the career of the individual (Ericsson, 2006).

Beyond the normal stages of skill acquisition, those of exceptional skill continue to improve their performance when others would plateau (Ericsson, 2006). This additional stage represents the student exceeding the teacher (Ericsson, 2004). During this stage regular daily practice continues to increase skill performance. Just like in the other stages these gains are gradual and continue regardless of the starting age of the skill.

This stage requires sequential tasks that are monitored for achievement. The focus is on a specific aspect that requires feedback but improves with repetition. The task must be beyond current regular performance but achievable within hours (Keith & Ericsson, 2007). Achievement of the new level of performance represents a new stable state. The sequence goes from one stable state to the next.

These states enhance the mediation of performance. This includes physiological aspects such as strength level, endurance, and muscular system speed for physical domains. It also includes cognitive aspects such as monitoring internal and external states during performance. All this mediation allows for better and quicker choices (Beilock, 2009).

Exceptional individuals are able to have more complex representations. Aspects that may be automated are examined to find nuances to focus on which can still push and challenge them in new ways to improve performance. This allows them to remain in the cognitive and associative phases rather than plateauing in the automated stage (Ericsson, 2004).

In order for an individual to be recognized as exceptional they must make some novel contribution to their field. This innovation requires more than just practice; it requires creativity (Lehmann & Ericsson, 1997). This will not be examined here but it is another quality common to outstanding performers that should be considered when determining what makes an individual exceptional.

There is much research on different aspects of skill acquisition, expertise, the impact of innate ability, and the relations between skills of different domains. Since much of this is quantified it could be implemented into a tabletop roleplaying simulation. This could then be a structure for designing computational models that need to simulate skill performance.

2.5 Game Mechanics

Not discussed much up to this point but just as important to tabletop roleplaying as character abilities, in the form of attributes and skills, are game mechanics.

A system's game mechanics refer to its rules, structure, and flow. When applied to roleplaying, game mechanics refers to how the virtual environment behaves and how characters interact with it. This includes how the character's attributes and skills are used, how uncertain outcomes are determined, how time is tracked, and any other features of the system not covered by the character's defined attributes and skills.

One aspect of game mechanics is surprise and unexpected events. What determines if an individual is surprised or taken off-guard and what affect does this have? This will in part be determined by the character's abilities but also by outside factors in the environment.

Deco and Rolls (2005) used evidence from neural activity in monkeys to define a model for expectation. They described attention as being part of a larger framework including action selection and short-term memory. In their model, the object of attention is kept in short-term memory. That in turn influences lower level processes and in part determines what is noticed.

Deco and Rolls (2005) measured the neural activity of the monkeys. Measurements were taken with the monkey expecting particular objects to appear in particular locations on a screen.

Their work showed the activity that takes place when expectations are changed. When items appear as expected then there is no change but once they start repeatedly appearing in a different location then there were changes in the occipital lob which is the primary visual center where information is processed before traveling to either the dorsal "where" or ventral "what" pathways. This preprocessing changed the way the data sent to these pathways was interpreted in a top-down manner (Deco & Rolls, 2005).

Measurements of neural activity confirmed that expectation could adjust to changing situations. Objects appeared in a particular position and repeated pattern. Then the pattern changed. If this change persisted, higher-level top-down notions were engaged. These in turn changed the rules in place to match the new expectations (Deco & Rolls, 2005).

The strength of this work is in the clearly measured results of reaction times and neural activity to support their model. The timing of these different aspects of attention could prove vitally important in situations where fractions of a second determine serious outcomes.

Itti & Baldi (2005) defined a model for distraction in an attempt to capture the affect surprise has on attention. They presented a Bayesian formula to model and quantified surprise. They measured how much participants watching video direct their gaze toward surprising events.

It is necessary to react appropriately to surprise in order to choose the best course of action. However, there had not been a way to quantify this phenomenon. At the neural level, unexpected or novel stimuli produce greater activity and contribute to learning and memory. Surprise captures attention and in this study it is measured by eye movement while watching video (Itti & Baldi, 2005).

To have surprise there must be uncertainty and an event that is different from expectation. This difference has to be measured relative to expectation, which is based on prior experience. If the new event does not change the previous held expectations, then it is not surprising. If it does change expectations, then this new model of expectation becomes the new basis for determining if future events are surprising. This allows for a unit of surprise to be quantified for a particular model, which can then be used in computations (Itti & Baldi, 2005).

Uncertainty and expectations are necessary for surprise. Expectations change as we are exposed to surprising events so a model of surprise needs to be able to update to these changes. The presented Bayesian model incorporated these updates and produced better results than other models (Itti & Baldi, 2005).

This was tested with human subjects watching video, monitoring their gaze by tracking eye movements. Eight participants were unaware that a surprising event would take place in the video. They watched 50 short videos about 30 seconds each back to back. The videos covered a range of day and night time natural and crowded scenes as well as television clips. Eye movement was measured in real time (Itti & Baldi, 2005).

Their formula was 20% more accurate than any other model at matching measured responses. Detecting outliers is not sufficient because things like continuous blinking lights are only distracting for a moment before they become expected (Itti & Baldi, 2005).

Some of the videos had more than one interesting target requiring multiple metrics to determine shifting gaze toward surprising stimuli. The results showed that the relatively few surprising locations were viewed by the majority of watchers and that human derived surprise garnered more attention than orientation or movement (Itti & Baldi, 2005).

Previous work focused on orientation, movement, and other primary features but had limited results in capturing human gaze, which correlates to attention. This work is an improvement. Previous work also defined novel stimuli as not appearing before in the test. However, this new work continuously updates and redefines expectations so it is not limited to a set of narrow predefined parameters. This model can also be applied to any of the senses (Itti & Baldi, 2005).

Even higher-level top-down factors can be quantified as within expectations or surprising and incorporated into the model. This can be used to detect and measure bias. These models combined with tests such as the eye tracking used in this study could be designed to detect cognitive disorders. Comparisons to and between animals could be made as well (Itti & Baldi, 2005).

This work presents a clear quantitative model backed with experimental evidence. This work could be used to model human attention and be useful for simulating situations dealing with the unknown and surprise.

Another game mechanic factor to simulate is the time required for target acquisition. For direct fire, this time is increased by a fixed amount for every doubling the range or halving the target width (Accot & Zhai, 1997). See direct fire target acquisition Equation 2:

$$T = a + b \log_2(A/W + c) \qquad (2)$$

For arched trajectories or tracing movements, every doubling the range or halving the target width doubles the time required to acquire the target (Accot & Zhai, 1997). See arched fire target acquisition Equation 3:

$$T = a + b\,(A/W) \qquad (3)$$

In both Equation 2 and Equation 3, T is time required, A is amplitude meaning the range to the target, W is the target’s width. The variables a, b, and c are constants representing the target independent minimum time needed to finish the task, the target dependent time factor, and a constant that places a lower limit on the target dependent time respectively.

To simulate the exact location of an injury, the above equations can be used to determine the amount a shot deviates from its intended location. This may still be enough to hit but along with direction determine the exact location on the body a hit lands. A shot to the head is much different than one to the foot. From here, the depth and effects of the wound can be determined using ballistic equations such as those presented by Nair & Rao (2012) and data on types of injuries such as those presented by Bruner, Gustafson, & Visintainer (2011).

With the proper attributes, skills, and game mechanics in place, various scenarios can be accurately simulated with a tabletop roleplaying structure.

2.6 Tabletop Technology

The tabletop roleplaying structure is a pen-and-paper format. This means it is not implemented with computers. However, it is a template to implement into computational models. Therefore, it is worth considering how these computational models should be implemented to maximize the simulation benefits roleplaying offers. These computational models could naturally be implemented as games.

Many video games are called roleplaying games and they have origins in pen-and-paper roleplaying games. However, many aspects of this older mode of game play are not being captured. Different technologies could be used that are more conducive to roleplaying activities such as touch surfaces, tablets, and tangibles. This would better capture the nature of roleplaying.

Video roleplaying games capture some of the aspects of the original format but there are significant differences. Comparisons between pen-and-paper and video roleplaying games have been made but can only be done with superficial matters (Tychsen, 2006). There has also been research into the possible formats these games could take to include more technology like the ones mentioned in Eyles & Eglin (2007).

Pen-and-paper roleplaying games have means of interacting not normally captured with computers and video games, even video roleplaying games. Such interactions include; the use of dice for task resolution, physical maps and miniatures for representing the location of individuals and objects in space, and face-to-face interactions to capture the subtleties of human social interactions such as tone of voice and facial expressions.

Rolling dice is an integral part of many pen-and-paper roleplaying games. Dice are used to resolve conflict. They add an element of chance. These aspects can be captured by a computer randomly generating numbers. However, even if virtual dice are displayed on a screen it is not the same as tangible dice that the user can hold and shake, which are important elements that increase engagement (Hsieh, 2012).

Maps and miniatures are not always used but they do provide an exceptionally intuitive way to keep track of precise locations of multiple individuals and their relations to one another. Translating this 3D scene to a flat monitor results in some degree of lost immersion but a multi-touch surface as the map and tangible figures with sensors or markers as the miniatures to represent the individuals can preserve and even enhance immersion (Mazalek, Mironer, O'Rear, & Van Devender, 2008).

Face-to-face interactions are arguably the core of pen-and-paper roleplaying games. In fact it does not even seem appropriate to call a game without this crucial feature a "roleplaying game". Complex human interactions and social issues can be difficult to convey on a screen but face-to-face interactions handles these matters naturally (Waskul & Lust, 2004).

Video games, even when they are online and involve and interact with other players, do not afford the depth or breadth of face-to-face interactions (Voiskounsky, Mitina, & Avetisova, 2004).

Despite all the advancements in graphics and sound and the coolest titles, video games are not as immersive as real world activities. This has been shown with training tasks that require hands on experience (Page & Smith, 1998). Similarly, changing an interactive setting with real people and objects to a screen results in a loss of immersion, engagement, and benefits gained from roleplaying.

When the participants sit at a table together and have tangible devices that are similar to ones normally used, then the types of interactions that normally occur are preserved even when the table and devices have computable software attached (Magerkurth, Stenzel, & Prante, 2003).

Extensive use of additional technologies such as an interactive game table, a wall display, personal digital assistants, and public loudspeaker have been shown to enhance immersion beyond the experience without this technology (Magerkurth, Memisoglu, Engelke, & Streitz, 2004).

Roleplaying is a beneficial tool for training, decision making, and forecasting (Green, 2002). So for the most accurate simulations perhaps technology should not necessarily replace every aspect of inherently social interactions like roleplaying games. Players still want to roll dice and sit at a table with their friends. However, perhaps cameras can capture the results of these dice rolls and outcomes can be automatically computed. Also alerts and secret messages can be sent discretely to an individual's hand-held device when passing a paper note or telling everyone would detract from the intended secretive nature of a particular communication.

Integrated technology could portray aspects of the simulation or provide a more immersive experience within a tabletop roleplaying environment, which results in greater learning and retention (Squire & Jenkins, 2003). Since tabletop roleplaying has aspects in common with board games such as participants sitting in close proximity around a table and manipulating physical artifacts, technology used in board games could be applied to tabletop roleplaying as well (Tychsen, 2006). This includes map views on a smart table or personalized messages, images, or audio sent to individual players' mobile devices or earphones (Lankoski and Heliö, 2002). Automated technology could perform computationally intense calculations such as ballistic results as well as capturing and evaluating details of a roleplaying session such as exposure to line of fire and response times. Such evaluations are useful for training and planning (Shute, Ventura, Bauer, & Zapata-Rivera, 2009).

Technologies such as smart tables and mobile devices have been used to increase engagement in board games, (Magerkurth, et al., 2004; Mazalek, Mironer, O'Rear, & Van Devender, 2008). The goal of these works was to increase the entertainment value of the games. Even though roleplaying games were used in some cases, the focus was on the board game aspects.

Magerkurth, et al. (2004) presented the incorporation of mobile devices and headsets for private and personalized information to individual players, as well as using a touch table, wall displays, and speakers for experiences shared by all participants. Their goal was to increase the enjoyment of the games.

Magerkurth, et al. (2004) presented a hybrid created between board games and computer games to increase enjoyment. The social interaction of board games was maintained and technology was used to handle aspects of the game that may distract from engagement such as keeping records and performing calculations. The technology was also used to enhance interactions by replacing a static board and playing pieces with dynamic interactive devices.

An adaptation of the Monopoly™ board game included a rotational display of the game board so the current player could have a better view of the text. Money and the cards were replaced with virtual versions. The wall displays were used to show the status of the players. A new feature was added to the game to allow for private transactions between players displayed on their mobile devices (Magerkurth, et al., 2004).

A second adaptation was a fantasy roleplaying game involving multiple players working together to explore dungeons, defeat monsters, and search for treasure. The table was used to display an interactive map of the current view that changed when new regions were explored. The wall display was used to show a full map of areas explored.

The speakers were used to imitate sounds in the dungeon. The mobile devices were used to keep track of individual player information and along with the headsets also used to send private information. Physical miniatures and dice were kept because manipulating these items increases engagement (Magerkurth, et al., 2004).

Their system was tested with eight different groups of girls with ages ranging from 11 to 14 during a Girl’s Day event. The participants were videotaped and interviewed afterward to talk about their experiences. All participants enjoyed the system and all were observed to be highly engaged in the game with many social interactions (Magerkurth, et al., 2004).

The ambitions of Magerkurth, et al. (2004) knock down barriers and expand horizons on what is possible with tabletop games. The techniques introduced here could be adapted in many different ways to incorporate many new and different elements never before seen in a tabletop setting.

Mazalek, et al. (2008) presented the use of a multi-touch table and camera to track the position of multiple objects in a modified version of the Dungeon & Dragons® roleplaying game. They wanted to explore this medium to increase social interactions compared to on-line games by having face to face game play while also improving the engagement of traditional tabletop versions by using interactive features.

Mazalek, et al. (2008) incorporated a similar system to Magerkurth, et al. (2004) but had the advantage of being able to track multiple objects simultaneously in real time. This eliminated the need for a turned based structure for multiple players.

The rules were based on the Dungeon & Dragons® roleplaying game. The objects were tracked on the table surface and the display was projected from above (Mazalek, et al., 2008).

Whether or not certain actions could be taken had to first be validated by the system. This was to ensure that the current position of a character allowed for the proposed action. For example, one can’t open a door unless they are able to reach it (Mazalek, et al., 2008).

Another significant advantage this system had over Magerkurth, et al. (2004) is the ability for each player to be able to freely move their playing piece independent of the actions of the other players whenever they chose, unrestrained by a turn based game (Mazalek, et al., 2008).

The system was tested with groups of three at a time. The participants were young adults with experience playing either traditional tabletop roleplaying games or on-line versions. Play lasted for 40 minutes and was monitored and video recorded. Afterward the participants were asked about their experience. The feedback was positive. The participants enjoyed the system over online versions because the face-to-face play made communication easier and promoted teamwork. It was easier to begin play than traditional tabletop games because the bookkeeping was handled by the system. This use of the system was seen as intuitive but could have incorporated more feedback like sound and visual cues (Mazalek, et al., 2008).

Although this system had the advantage of multiple tracking, it had several limits that Magerkurth, et al. (2004) did not. These included the limits of a projected display from above to the table that was disrupted whenever someone reached across or even onto the table. The display appeared distorted on the person's arm. The playing pieces were generic and so not easily distinguishable. The board was smaller and required all playing pieces begin at starting positions for each new map display.

There were also a very limited number of actions the players could have their characters take. Although they indicated, future work would expand these options (Mazalek, et al., 2008).

There are several online commercial software products for tabletop roleplaying games that provide interactive maps and sheets for keeping track of character abilities. Aspects of these products offer format suggestions for implementing a tabletop roleplaying simulation structure as a computational model.

2.7 Simulation Training

Simulations are methods for implementing representations of entities, processes, phenomenon, or systems. Simulations can be implemented with different media, including pen-and-paper roleplaying in which people act out many of the representations. This is ideal for simulating human behavior and interactions. For computational models meant to be implemented on computers, the representations are based on quantified variables and mathematical equations; this is ideal for representing things like physics which roleplaying alone would not handle with the same precision and accuracy.

Simulations can be excellent tools for training when it is too expensive, dangerous, or difficult to train under real conditions. This ranges from military exercises (Page & Smith, 1998) to medical training (Shapiro, Morey, Small, Langford, Kaylor, Jagminas, Suner, Salisbury, Simon, & Jay, 2004) and includes repetitive tasks that are more cheaply done by a computer or other simulation. The effectiveness of simulations has been shown but the closer the simulation is to the real activity, the more real world transfer occurs, (Nikendei, et al., 2005).

Simulations can use virtual worlds, which can also incorporate roleplaying elements. The study of virtual worlds is discovering the research potential with this media to expand knowledge in sociology, psychology, economics, and human computer interaction (Bainbridge, et al., 2007).

Regardless of the format it should be clear that both roleplaying and computational models have their strengths and limitations. When combined, a much more immersive and accurate simulation environment can be generated.

Tabletop roleplaying traces its origin to military planning. The purposes of these early tabletop simulations were to test abstract ideas and discover effective strategies.

Another example of making discoveries from models are personnel assessments. The intent is to use principles from psychology and cognitive science to discover which qualities best evaluate individuals and predict performance. This makes them of particular interest for capturing human abilities in roleplaying simulations because the measures used in these assessments may also make good attributes for roleplaying.

The results of personnel assessments are used by institutions for everything from adjusting business strategies to determining job placement (Judge & Bono, 2001). These models have distinct measurable categories for various cognitive abilities (Mount & Barrick, 1998). However, evidence suggests that overall or general intelligence plays a larger factor than these individual categories for determining an individual's performance (Schmidt & Hunter, 2004).

There is a definite need for more accurate simulations that account for human behavior, decision-making, and group dynamics, (Page & Smith, 1998; Shapiro, et al., 2004). For these types of situations roleplaying offers improvements. This could include simulation training.

Page and Smith (1998) try to communicate to simulation designers from the military perspective by clarifying the meaning of terms they use. In doing so they also express in part the simulation needs of the military. There is a definite desire to have any software run on multiple different platforms. This could range from desktops, laptops, smart tables, to mobile devices. They defined some of the distinctions and techniques used by the military for their simulations. This included using random sampling to estimate unknown values.

A distinction is made between real people and simulated people. Similarly a distinction is made between real systems and simulated systems. All these combinations of people using systems are used. However, when simulated people are using simulated systems, they receive input from real people. There are no simulations completely free of real people. Capturing aspects of human behavior is limited without human input (Page & Smith, 1998).

Page and Smith (1998) have the strength of providing a voice from the military perspective and can shed insight into that domain. Military actions align closely with active-shooter events with similar simulation needs. This includes the necessity of having human participants working together to accurately simulate human decision making and interaction as well as developing teamwork. The fact that the military does not have any human free simulations speaks to the limitations of current computational models that need to be addressed.

Shapiro, et al. (2004) expressed the need for better simulations to model teamwork in medical emergencies. A new simulation was introduced based in part on ones used in aviation for teamwork and in part on simulations used in anesthesiology that incorporated a dummy with embedded computers to simulated medical conditions. Their version replaced the dummy with roleplaying. Two teams of doctors and nurses were sent through the simulation. Their teamwork skills were evaluated before and after the simulation and compared to two other teams that did not go through the simulation. The evaluators were blind to which teams went through the simulation.

The simulation was created by domain experts who in this case were experienced emergency room personnel as well as psychology experts in designing simulations for group dynamics. This had already been done with the aviation based teamwork simulation. In addition, similar medical simulations existed for anesthesia-based scenarios but those were not team-based exercises (Shapiro, et al., 2004).

Better teamwork reduces the chance of errors by making it more likely they will be noticed and handled. This will lead to a safer environment for the patient. To create better teamwork there must be more attention paid to human performance (Shapiro, et al., 2004).

Both the experimental and comparison teams went through teamwork training prior to the simulation. Each team consisted of two doctors and three nurses. Everyone participating in the simulation training was at the time, employees at the same hospital. Their work schedules were secretly adjusted to ensure the individuals would work together so they could be observed working together before and after the simulation. The participants did not know whom they would be working with before starting the simulation. The comparison group spent one extra shift working together instead of going through the simulation. Observations of the teams prior to the experimental group going through the simulation indicated the control group and experimental group did not have significant differences (Shapiro, et al., 2004).

The simulation lasted eight hours and included three different scenarios of increasing complexity. Participants were observed through one-way glass and recorded by video. The session ended with a debriefing of teamwork related questions. They were observed again within two weeks after going through the simulation (Shapiro, et al., 2004).

This study's results showed the teams that went through the simulation did experience improvements in teamwork skills but not significantly over the comparison teams. This was seen as a failure (Shapiro, et al., 2004).

However, there is another way to look at these results. Rather than focusing on the simulation groups not being significantly better than the control, realize they were just as good. The control group worked an extra shift together with real emergencies and real patients. The simulation training was as effective as a real shift in an emergency room without the dangers and risks involved with real emergencies. This allows for training under safe conditions with no risks to real patients. This is ideal for training new doctors and nurses. It is also ideal for simulations of rare events that do not allow for frequent real experience.

Medical teamwork training existed before this but not a simulation for medical teams. There were simulations that taught or evaluated individuals but interactions with other people were role-played by individuals not being taught or evaluated (Shapiro, et al., 2004).

The strength of Shapiro, et al., (2004) is the recognition that to simulate a situation involving a group of people having to work together as a team you need to include such a team of people in your simulation, not just one individual.

The results actually show that teamwork simulations can be as good as real experience. Perhaps the simulation could give even better results because it can condense particular scenarios into a limited period. The details of the simulations are not explained so it is difficult to duplicate or improve upon without additional information but the complaints by the participants about the simulation not being realistic could be addressed by incorporating more detailed variables and factors focused on increasing realism (Shapiro et al. 2004). Simulations have been shown to be useful training tools (Nikendei, et al., 2005) and predictors of behavior (Green, 2002). Shapiro, et al., (2004) exemplifies that even when simulated conditions do not exactly match those of the real world, the training can still be effective with the added advantage of being safe and less costly.

For this dissertation, I attended and participated in several active-shooter live-action simulations. I took copious notes at these training exercises and asked many questions. All of this information went into the design of the tabletop roleplaying structure for simulating active-shooter events.

2.8 Active-Shooter Events

Anklam, et al. (2015) defines characteristics of active-shooter events and gives a definition as "…Individual actively engaged in killing or attempting to kill people in a confined and populated area…" A major factor is time. The longer these events last the more people are killed with an average of one every 15 seconds. An average active-shooter event lasts 3 to 4 minutes but the fastest police response is 5 to 6 minutes. The sooner the active-shooter is engaged the less people will be killed.

Anklam, et al. (2015) sites historical events to show that having armed personnel on location for the sole purpose of security greatly reduces the time to engage an active-shooter. They also point out from numerous studies that enacting laws enabling individuals to be armed reduces violent crime in those areas. This includes school campuses. Criminals migrate to areas where individuals are not armed, such as "gun-free" zones like schools.

Anklam, et al. (2015) further emphasizes the significance of having armed personnel on site by running agent based simulations of schools with and without armed resource officers. These simulations showed great reduction in engagement time and people killed by having an armed resource officer.

Anklam, et al. (2015) state that the best way to model "human systems" is to use agent-based modeling. Claiming it allows for complex interactions and behavior, which they state, are required for modeling active-shooter events. However, roleplaying has been shown to do a better job at modeling human interactions and behavior (Green, 2002).

Anklam, et al. (2015) also lists the limits of agent-based models. In the real world humans have free will and are not restricted to predefined actions. Therefore, agent-based models involving human interaction, behavior, and decision-making will not be completely accurate. These restrictions are removed with roleplaying. The accuracy of these agent-based models could be compared to simulations, using roleplaying (Green, 2002).

Some or all of the following could be role-played: the perpetrator, the unarmed by-standards, the armed resource officer, the armed concealed-carry workers, and the first responders. The results could be compared to the agent based model and the actual event being portrayed. This would replace random movement by the active-shooter with decisions of the person portraying the active-shooter character. Rather than assuming the behavior of concealed-carry workers and others, these would be role-played by human participants. This would allow individual responses based on human emotions, understanding, values, and decision-making qualities not easily captured by programmed AI agents.

Incorporating tabletop technology would allow for multiple variations in school layouts to easily be implemented. This would play a factor in decision making of both the active-shooter and those responding to him.

Frazzano & Snyder (2014) proclaim the definition of active-shooter event is too narrow for all possible related violent attacks. Too much emphasis is placed on the use of firearms. They suggest a broader term Hybrid Targeted Violence (HTV) to accommodate the use of traps, explosives, attacks using fire, and unconventional tactics as well as the use of firearms.

Additionally, Frazzano & Snyder (2014) state that the traditional methods; by police, fire, and emergency medical responders; need to change. Instead of fire fighters and medics waiting for police to secure the area before entering, they need to take a more active and immediate approach to the situation because lives could depend on it. Coordinated efforts are needed. Medical personnel could be guided in and covered by a police escort to get them to injured victims. Police could be cross-trained as medics. These are just some strategies being implemented by first responders in particular cities.

Frazzano and Snyder (2014) stress the need for coordinated training and planning to develop and implement comprehensive techniques. Police, fire, and medical personnel need to work together to imagine various collaborative “if-then” scenarios when developing or evaluating their collaborative strategies. Tabletop methods are mentioned as the means to achieve these interactions.

All of this could be accommodated with tabletop technology to display maps with various scenarios. Unlike waiting for experience with an actual HTV or the resource intense live-action event, tabletop simulations could be run multiple times a day with various modifications. These simulations could include situations where deliberate fires were set and a variety of other scenarios. Each participating organization may suggest new possible obstacles that others might not even consider. Each running of the simulation could offer opportunities to learn something new. Additionally, if this were an online tool it would make it easier for different departments to partake in the simulation together and learn from one another.

For this dissertation, I communicated and met with multiple police departments and police organizations. They were all interested in having tools for better simulating active-shooter events that they could implement more frequently for both training and planning purposes. They stated that having such a tool would help them be better prepared and able to protect and serve the public.

CHAPTER 3: METHODOLOGY

The goal of this dissertation was to develop a better structure, based on tabletop roleplaying, for designing computational models simulating active-shooter events.

3.1 Approach

The approach began with research showing simulations involving human interactions and decision making with a limited number of individuals can benefit from incorporating roleplaying (Green, 2002). Roleplaying games can become better simulations by incorporating knowledge from scientific research to the rule mechanics and the defined abilities of the portrayed characters. If the nature of these rule mechanics and defined character abilities are quantified and expressed formulaically, they will form an implementable structure for improving current computational models.

A tabletop version of roleplaying was used. The reason is that many such existing games already have abilities and rules that are quantified and defined with formulas. Many of these games also go into more detail on events involving physical conflict. Along with this is the strength tabletop roleplaying offers in its ability to represent relative distances and positions, particularly when maps and miniatures are used. All of this made police and military exercises the best candidates for events to simulate. From here, active-shooter events were chosen due to the availability of data and research and the potential to help police save lives.

This work required three steps. The first step was to create a tabletop roleplaying simulation of active-shooter events based on the principles in the covered research. The second step was to confirm this tabletop roleplaying structure was a valid means for simulating active-shooter events by showing it produces superior results compared to current computational models. Then once this was established, the third step was to capture roleplaying aspects of these tabletop roleplaying simulations in a quantitative way that would further define the structure so it could serve as a template for improving computational models.

These three steps were done. For this dissertation, I created a tabletop roleplaying structure for accurately simulating active-shooter events based on the covered research. I then ran multiple sessions of this tabletop roleplaying structure to validate it as a superior means of simulating active-shooter events compared to current computational models and the average of several real world active-shooter events. I then ran multiple tabletop roleplaying sessions using this same structure to simulate one particular active-shooter event. Modifications were then made to the latter sessions in this second group to improve the structure's performance and quantify more roleplaying aspects. This defined a structure for designing and implementing into computational models to improve their performance.

The first step of creating a tabletop roleplaying structure for simulating active-shooter events required using my over thirty years of experience running tabletop roleplaying games and over twenty years and tens of thousands of hours with tabletop roleplaying design. It also required vast knowledge gained from the extensive research covered from wide ranging disciplines. This was done and explained below in detail in the Explanation section.

The second step of establishing the strength and superiority of tabletop roleplaying to current computational models required running tabletop roleplaying sessions of an active-shooter event. Then compare these tabletop roleplaying results to results from a computational model simulating the same event. Then both data sets would be compared to real world data of actual active-shooter events. This was done. The details are explained in the Explanation section below.

The third step of capturing roleplaying aspects in a quantitative way so the structure can act as a template for improving computational models designed to simulate active-shooter events required defining attributes for the characters. These attributes had to improve the simulation when compared to real world data. This was done. The details are explained in the Explanation section below.

The focus on active-shooter events was due to availability of information and the good it could provide to the community by assisting police. However, this structure has no properties that limit it to just these types of events. During design, sight was not lost on the possibility of this structure being used more broadly. Many other types of police exercises and military operations share much in common with active-shooter events. The structure was designed with the possibility of expansion in mind.

3.2 Accomplishments

For this dissertation, I have produced a structure for creating better computational models based on tabletop roleplaying. This work is in the form of a defined structure for improving simulations of active-shooter events. However, the application of this novel approach reaches far wider. The methods introduced here could apply more broadly to improve the accuracy of computational models designed to simulate any human behavior. This is a significant contribution to the field of artificial intelligent design.

Tabletop roleplaying has not been used to improve artificial intelligence. Resent work with tabletop roleplaying has focused on social impact (Taylor, 2019; Cook, 2017), educational use (Klopfer, 2017; Shabani, Ghafari, & Boroumandfar, 2020), or entertainment (Miśkiewicz, 2020).

The existent state of roleplaying games required substantial redesigning to achieve the serious use of accurately simulating active-shooter events. This dissertation incorporates several scientific concepts into the presented implementation. These were the first steps taken in a previously unexploited direction, creating an active-shooter event simulation from a tabletop roleplaying structure.

In this dissertation, I proved that this tabletop roleplaying simulation produces data closer to an aggregate of real world data from multiple active-shooter events than the industry accepted AnyLogic® computational model used in Anklam, et al. (2015).

I also proved that this roleplaying simulation can accurately simulate a specific active-shooter event and this accuracy is greatly improved when attributes are added.

I have defined this tabletop roleplaying structure in formulaic and quantitative ways so it can be implemented into computational models designed to simulate active-shooter events to improve their performance. Having a structure for designing better computational models for active-shooter events is a great benefit the public.

I have shared this structure at various stages of development with multiple police departments and police organizations. The validity of this structure was also confirmed by having these police officer active-shooter event experts, evaluate it after participating in tabletop roleplaying sessions. They found it insightful and felt it would be useful. All were interested in this work and stated it would improve their training and preparedness for active-shooter events.

The cost and logistics of having a live-action active-shooter training exercise prohibits police departments from running them more than one or twice a year. This structure is a template for implementing computational models that could be ran every day. This allows more “what-if” scenarios to be run, allowing the police to be steps ahead of potential new threats they may face. It also introduced ideas they had not considered before including adding a random factor to determine the results of actions with uncertain outcomes.

The capacity of roleplaying games to cover a vast range of subject matter makes them well suited to simulate the wide range of topics that may arise in an active-shooter event. Perception, senses, memory, training, language, attention, knowledge, and even neurological structures can all be incorporated into a tabletop roleplaying simulation; trauma to the brain could affect attributes based on the location of the brain injury.

The uses for such a model are vast. Roleplaying is capable of simulating the wide range of human emotions, interactions, and decisions. Tabletop roleplaying adds the capacity to simulate relative positions and distances of people and objects. Advantages to simulated exposure are capturing aspects of the real thing but with less risk.

As a simulation of violent conflict, active-shooter events, this tabletop roleplaying structure is suited for use as a training tool to simulate various dangerous, costly, or impossible scenarios. It could be used to simulate disaster or combat situations for planning and training purposes, capturing the impact stressful situations have on decision-making. This includes simulating events for military and emergence personnel, allowing them to be better prepared to deal with the challenges unique to their operations.

A degree of stress and fear was observed in the participants of the tabletop roleplaying sessions. This tabletop roleplaying structure can capture things like the fog-of-war or panic and their effects on the ability to perceive your surroundings, process information, and make decisions. Fog-of-war is a term used to describe the confusion, disorientation, misinformation, and lack of information that occurs in the middle of combat or other similar chaotic events.

The fact that this tabletop roleplaying structure is a serious game means that its use is naturally engaging perhaps more so than other training methods. It combines the benefits of serious games with those of simulations and opens the doors to completely new training methods and areas of research.

This tabletop roleplaying structure bridges the gap between human behavior and artificial intelligence. It is a template for creating better artificial intelligence for simulating a wide range of events, not just active-shooters. The structure is well defined in quantitative ways so it can be implemented into computational models with the role-played characters replaced with AI agents. To design better computational models using this tabletop roleplaying structure, follow the steps in Table 1:

Table 1: How to use tabletop roleplaying structure

Step1: Run Sessions of the Event to Simulate, Using this Structure
Step2: Observe Behavior
Step3: Quantify Any Unaddressed Behavior
Step4: Get Input from Experts
Step5: Update Structure Based on Steps3&4 (if updated, go to Step1)
Result: Model Prime for Computational Implementation

Another approach is to use this tabletop roleplaying structure to implement desired behaviors and then use this as a foundation to construct AI. The process of instantiating desired behavior into a tabletop roleplaying format creates a quantified and formulaic structure prime to be implemented into an AI computational model. Like the use for simulation training, this could be a cost saving endeavor.

This tabletop roleplaying structure can be used to instantiate theories and models and test their validity. This could range from police or military tactical theories to cognitive science models. It is beneficial to consolidate multiple models to truly understand cognitive processes (Davis, Butcher, Docherty, Meaburn, Curtis, Simpson, Schalkwyk, & Plomin, 2010). This would help address the issue of disjointed models explaining a consolidated human mind (McGrew 2009).

This is a tool for testing promising concepts, which may otherwise have to remain as theory or require more traditional and possibly costly means to confirm. This tabletop roleplaying structure offers a way to try out new tactics and models and can even suggest new directions. Users would learn concepts incorporated into the structure simply from participating in the tabletop roleplaying simulation, even if they only treated it as a game for entertainment purposes.

This tabletop roleplaying simulation could be used to teach participants about the cognitive and physical differences of others. This could range from minor cultural differences to understanding the challenges of those with sever cognitive or physical impairments and even gain insight to the cognitive abilities and limitations of artificial intelligence.

This is made easy because of another great aspect of tabletop roleplaying, the ability to assume the role of someone or something you are not. Assuming another role grants one a glimpse into how the world can be viewed from a different perspective. This insight is made all the greater from the scientific research used to form this tabletop roleplaying structure of active-shooter events.

3.3 Explanation

Creating a tabletop roleplaying structure for the serious use of simulating active-shooter events required examining existing tabletop roleplaying rule sets with consideration on how to implement principles from the relevant research. The structure of the tabletop roleplaying rules and character attributes were designed based on scientific principles to produce accurate simulations of the real world. This structure also had to be expressed with equations and quantified variables so it could be implemented into computational models.

This began with the game mechanics, the overarching rules that applied to the entire simulated world independent of individuals in it. Then the individual people in the simulated world had to be able to interact with it and each other. To create uniqueness between individuals, quantified attributes had to be implemented that accurately captured these differences in a tabletop roleplaying format.

Page & Smith (1998) was referenced for making many of these decisions since they present how the military addresses many of these issues and there are several similarities between certain military exercises and active-shooter events. Other referenced research was used to guide and support structural design decisions as well.

There are many different tabletop roleplaying games and the rules in these systems vary greatly. Dozens of different games were examined. The list of hundreds of published tabletop roleplaying games was reduced significantly to ones with a focus on simulating the real world. It is often possible to study a tabletop roleplaying game’s rules separate from the setting of the fictional world. These rules are referred to as the game mechanics or system. The focus here was on these game systems.

Systems published as games for entertainment could have serious usefulness. Tabletop roleplaying was derived from tabletop war games designed to simulate real world conflicts. Inherently many of these games have serious simulation properties and some have been intentionally designed for this purpose despite being published as a game for entertainment. As an example, Phoenix Command® was created by Barry Nakazono (1986), a NASA propulsions engineer. His game system goes into elaborate detail regarding the types of injuries caused to the human body from various types of weapons and the effects these injuries have on the victim. This was based on military wound data. This and other systems like; Guns!, guns!, guns!® created by Greg Porter (1988), extensively cover ballistics, based on physics equations, properties, and units used to study real world ballistics. Inspiration and guidance was taken from these and other existing systems, however a new structure was created for this dissertation research.

The terms used for this tabletop roleplaying structure were selected to stress how they are used here. First, rather than the term “game” the terms “simulation” or “structure” are used to emphasize its serious purpose. For the individual overseeing the simulation the term “moderator” is used instead of “game master”, “judge”, or “referee”; this indicates that the focus is to be on the other participants. The term “player” is still used to refer to these other participants.

One major game mechanic component is how to deal with time. One distinction is between discrete event based and real time models. The military uses the former more for larger scale simulations in terms of both troop size and time measured in hours and days.

The latter is used more for smaller scale units with time measured in seconds and minutes (Page & Smith, 1998). Most tabletop roleplaying games use some type of discreet method such as rounds or turns to track time. However, according to Page & Smith (1998) the military uses real time to simulate these types of events rather than a discreet event based method of tracking time. Therefore, a form of continuous time was used.

The term continuous time is used because it is not possible to run a tabletop roleplaying session in real time. It takes longer to describe and resolve some actions than it does to execute them in the real world. For example, it takes a fraction of a second for a bullet once fired to hit or miss its target, this usually takes at least a few seconds to resolve using tabletop roleplaying.

Therefore, this is not real time but is continuous time. This means it is not on a one for one ratio. It is not even at a fixed ratio since some things will take proportionally longer to resolve than others, when comparing them to the real world. However, it is continuous in the since that there are no artificial units of time like rounds or turns where things reset or start over. The time management subsystem used here drew on my over thirty years of experience with tabletop roleplaying. It is based on a system I created, although others have used similar systems. I have implemented it successfully in hundreds of previous tabletop roleplaying sessions.

Time is tracked and continuously progressed by the moderator. Every action requires a certain amount of time to complete. When one action is finished, another one can be started. All individuals can act simultaneously. Some actions can be done simultaneously as well but often with a penalty to the chance of success. An example is walking and shooting is less accurate that standing still and shooting.

With this method, the moderator announces to all the players the current time and updates them when and how much time has passed in the simulated world. Then it is the responsibility of the players to update their characters' positions, actions, etc. The moderator could be with one group of players without needing to announce to the others the time passing unless something that took place could affect what the others were doing. Seconds were used for simplicity. Smaller units could be used for more precision.

Rules were defined to determine times required to complete various tasks. One big example is the time required to move a character on the map. Some tabletop roleplaying simulations use rulers to move figures on the map and the distance moved depends on the scale and the amount of time but this usually involves only a couple of players. For my simulations, to prevent a couple dozen players from obstructing each other with everyone laying down their rulers, a grid system was used with each square representing 10 feet. The time it took to move one 10 foot square depended on how the character was moving: crawling, walking, or running. When multiple diagonally moves are made the time could be increase by a multiple of 1.5 for a rough estimate; 1.41 would be more precise. Other tasks that were likely to be taken were assigned times as well. This included the time required to open, close, and lock different types of doors.

Guidelines for the time required to complete various tasks was first derived from exiting tabletop roleplaying games that focused on simulating the real world; including Nakazono (1986) and Porter (1988). Then this was modified to incorporate and account for the reviewed research. From here, the values were confirmed or adjusted based on feedback from police officers at Columbia South Carolina SWAT and the South Carolina

State Active-Shooter Training Program. The results are listed in Table 2. Multiple copies of Table 2 were printed out and made available to all the players during the sessions.

Additional tasks were made available for characters with weapons. This included the time required to draw a weapon, aim, shoot, and reload. These times were also originally based on existing tabletop roleplaying systems (Nakazono, 1986; Porter, 1988) but then also refined from research and verified by police. These times are listed in Table 3. Copies of Table 3 were made available to the characters with access to firearms; the shooter, the police, and when present the resource officer and concealed carry faculty members.

Table 2: Tabletop roleplaying simulation basic rules

Roleplaying Simulation Rules

1. Success/Failure
    a. d6 1-3 = Failure, 4-6 = Success
    b. Difficult tasks require more consecutive Successes
    c. Modifiers increase or decrease the number of Successes required
    d. Below 1 Success are increased attempts (granted Failures) at a Success
2. Map
    a. 1 Square = 10’
3. Time to move 1 Square
    a. Crawl: 3 sec
    b. Walk: 2 sec
    c. Run: 1 sec
4. Doors
    a. Open Door: 1 sec
    b. Close Classroom/Office Door: 1 sec
    c. Close Other Doors: 2 sec
    d. Lock Door (turn latch) 1 sec
    e. Lock Door (key): 3 sec

Table 3: Tabletop roleplaying simulation advanced rules

Roleplaying Simulation Rules

1. Success/Failure
    a. d6 1-3 = Failure, 4-6 = Success
    b. Difficult tasks require more consecutive Successes
    c. Modifiers increase or decrease the number of Successes required
    d. Below 1 Success are increased attempts (granted Failures) at a Success
2. Map
    a. 1 Square = 10’
3. Time to move 1 Square
    a. Crawl: 3 sec
    b. Walk: 2 sec
    c. Run: 1 sec
4. Doors
    a. Open Door: 1 sec
    b. Close Classroom/Office Door: 1 sec
    c. Close Other Doors: 2 sec
    d. Lock Door (turn latch) 1 sec
    e. Lock Door (key): 3 sec
5. Combat
    a. Miss/Hit/Kill
        i. less than needed Successes = miss
        ii. needed Successes = hit
        iii. 1 extra Success = kill (lethal attacks only)
    b. Time
        i. New Target: 1 sec
        ii. Aim Time: 1 sec
        iii. Load Time: 2 sec
    c. Modifiers
        i. Attack Square blind: 3 more Successes needed
        ii. No Aim: 1 more Success needed
        iii. Brace: 1 less Success needed
        iv. Shooter Walking: 1 more Success needed
        v. Shooter Running (also no aim): 2 more Successes needed
        vi. Target Walking lateral: 1 more Success needed
        vii. Target Running in line: 1 more Success needed
        viii. Target Running lateral: 2 more Successes needed
        ix. Each x1/2 target size (cover): 1 more Success needed
        x. Each x1/2 base range: 1 less Success needed
        xi. Each x2 base range: 1 more Success needed
6. Weapons
    a. Pistol base range 6 Squares
    b. Shotgun base range 12 Squares
    c. Rifle base range 24 Squares

Another major component to game mechanics is how to determine the results of attempting actions with uncertain outcomes. Most tabletop roleplaying systems use dice to handled uncertainty. Dice were used here are well.

However, many different types of dice systems are used in tabletop roleplaying. There are dice with different numbers of sides. Most dice are numbered sequentially from one to the number of sides they have. When using these dice most tabletop roleplaying systems simple compare the die roll result to a value representing how difficult the action taken was to complete successfully, with higher numbers being harder to reach. The number the player is trying to roll or beat by rolling higher is often called the target number. These target numbers are often modified to reflect different conditions by simply adding to the target number to reflect conditions that are more difficult or subtracting from it to reflect easier conditions. Alternately, the modifier can be applied to the die roll instead.

The problem with this method is it can produce target numbers that are impossible to roll because they are too high or impossible to fail because they are one or less. Additionally a single modifier affects the odds differently depending on the original target number. For example if using a d20 (a dodecahedral die of twenty sides numbered 1 to 20) and the target number was 20, a reduction of the target number by one doubles the odds of success, a 100% relative improvement from 5% (1 in 20) to 10% (2 in 20) because now a 19 or 20 equals success. However, if the original target number was 11 using the same d20 the odds of success are 50% (11 to 20), the same reduction in target number changes the odds relatively less to 55% (10 to 20). This is a 10% relative improvement 55% over 50%. These types of issues do arise in tabletop roleplaying systems that use these types of linear dice methods, which is most of them.

Some tabletop roleplaying systems use multiple dice, known as dice pools with a set number on the dice always being a die success but multiple die successes are needed to succeed at a task. Modifiers or skill level determines the number of dice you roll. This eliminates impossible to fail tasks because all dice could roll failures but there is still the issue of impossible tasks to succeed because you do not have enough dice. There are also the relatively unequal effects of adding or removing a fixed number of dice to different starting number of dice.

Exploding dice is another option some tabletop roleplaying systems use. This is when a die is equal to a particular number or numbers the player rolls the die again. The result of the second roll is added to the previous roll or number of successes. This can continue on to a third roll and beyond. Exploding dice can be used with any type of dice and even combined with dice pools.

There is a way to implement exploding dice to follow the power log rule that is keeping with the research on observed action (Accot & Zhai, 1997), skills (Dehaene, 2003; Newell, 1991), and attributes (Stevens, 1957).

If using only one die and half the time it is a success and each success indicates roll the die again, then the odds of getting one more success will always be 50-50. The odds of one success are 1 in 2, the odds of two successes in a row are 1 in 4, the odds of three successes in a row are 1 in 8, and so on indefinitely.

The player keeps rerolling the die until they stop rolling successes in a row. After the first roll of a success, a reroll of a failure is not a failure, it just stops the number of successes. Now every one-point increase to the target number cuts the player's odds of success in half, regardless of initial odds.

This type of power log die can explode for failures as well. Since half the die rolls, are successes, the other half are failures. If the first roll is a failure, then the die is rerolled until it stops rolling failures. Really easy tasks may allow one or more failures and still count as a success. The mechanic of how the dice work is reflected in Table 2 and Table 3, one or the other is available to all the players during the tabletop roleplaying session.

The power log rule for skill acquisition (Dehaene, 2003; Newell, 1991) as well as the logarithmic equation for target acquisition (Accot & Zhai, 1997) directed the design principles of the dice for this tabletop roleplaying structure.

For this system, any dice with an even number of sides can be used. Even coins could be used with heads being a success and tails being a failure. For these studies, regular six sided dice (d6) were used because of their availability and familiarity. With six sided dice, 1 to 3 is a failure and 4 to 6 is a success, this is in Table 2 and Table 3, all players get a copy of one or the other.

The scale for dice, the modifications for dice rolls, and in study2 the value of the attributes all have a norm or base value of 0 and every 1 point is a doubling (+1= x2, +2 = x4, +3 = x8, etc.) or halving (-1 = x1/2, -2 = x1/4, -3 = x1/8, etc.) in magnitude or odds of success.

The impact modifications to the dice rolls have on the simulation are enforced by the dice system. The dice were used to determine the outcome of difficult tasks. A difficult task is any task that when attempted the outcome is uncertain. For example, shooting a target qualifies as a difficult task unless the target was not moving and at point-blank range (the weapon touching or nearly touching the target). However, closing a door is not a difficult task and would not warrant a dice roll unless there was some type of resistance such as someone else trying to keep it open or an obstruction.

For anyone portraying a character with a firearm, they need to know the outcome of shooting at a target. This includes the shooter, the police, and for study1 sessions that used them; the resource officer and concealed carry faculty members. This depends largely on range, movement, and time spent aiming. This is direct fire target acquisition so follows a logarithmic scale (Accot & Zhai, 1997). Therefore, the time needed to acquire a target doubles based on range. If the full time is not taken, the odds of success are cut in half. This follows our established die mechanics. This is reflected in Table 3 and made available for players portraying characters with firearms.

A variety of tasks and the odds of hitting targets with various weapons at different ranges have been defined and assigned odds of success. As with time values, these odds were initially based on existing tabletop roleplaying systems (Nakazono, 1986; Porter, 1988). They were then adjusted to conform to the reviewed research. Then they were confirmed or modified based on input from Columbia South Carolina SWAT team leaders and police representatives of South Carolina’s State Active-Shooter Training Program.

According to (Page & Smith 1998) capturing aspects of human behavior are limited without human input. The tabletop roleplaying structure used in these active-shooter event simulations introduces attributes in study2 to quantify some of this roleplaying behavior. Since these attributes are quantified, they can be incorporated into a computational model.

Attribute scores are quantified variables used to indicate differences between characters in the simulation. This is only used for some of the study2 sessions. All the other sessions treat all characters as the same in ability to complete any particular task.

Most tabletop roleplaying systems use attributes to define the characters. However, the type of attribute and their values vary greatly depending on the tabletop roleplaying system used. Here the scale and values need to match the dice mechanics and odds of success of the rest of the established tabletop roleplaying structure.

Tabletop roleplaying systems have different values for their norm or average score. However, if the norm is zero and the magnitude is on the same scale as the rest of the system then the attribute scores can simply be added to the dice rolls to affect the odds. Positive values make it easier to perform related tasks; negative numbers make it more difficult.

The numerical values are on the same logarithmic scale as the dice. These attributes consist of variables for size and strength, speed and coordination, cognitive abilities, and personality traits. The norm value of the attributes is zero with a standard deviation of one for a random adult from the general population.

However, the norm for these variables are adjusted based on age, role (faculty, staff, or police officer), and for adults whether the individual is a man or woman because these more narrow segments of the general population have different norm values.

The impact these attribute scores have on the simulation are based on their magnitude, which are on the same logarithmic scale as the dice. However, these values are randomly generated and the frequency of any particular value matches its frequency in the real world.

For example, a character would have a score of 1 if they were twice as likely to succeed at a particular task, than an average individual was. However, the frequency that a character has a value of 1 for a particular attribute is based on the frequency that a particular individual in the population would be twice as likely at succeeding at tasks involving that particular task. For this tabletop roleplaying structure, this translated to 1 standard deviation or the 84th percentile of the population or approximately 1 in 6.3. This scale of one standard deviation equaling one point on this logarithmic scale produced accurate results but the ratio could be adjusted for particular attributes if needed.

For example, the senses were measured to have different detectable levels for the different senses but all were on logarithmic scales (Stevens, 1957). Recording all values on a logarithmic scale simplifies translating from one to the other. With both modifiers, dice, and attributes on logarithmic scales, translating the attribute to match the dice and modifiers would only require multiplying the attribute by difference in rate it affects the simulation (Stevens, 1957).

If for example the impact an attribute has on the simulation doubles every 2 standard deviations instead of every 1, just half the attribute score. Alternately, to avoid fractions, double the values in the rest of the structure. All modifiers and target numbers would be doubled. What once required one success, would now require two successes. For this, different sided dice are suggested to allow for single (previously fractional) successes. You can also do this for more precision; allowing values between doublings.

For example, if you triple (x3) all values you could have two six -sided dice (d6s). The first would be read as follows: 1 = -3, 2 = -2, 3 = -1, 4 = +0, 5 = +1, 6 = +2. The second die would be read as follows: 1, 2, or 3 = stop, 4, 5, 6 = ±3 (if the first die is negative then -3, if the first die is 0 or more then +3) & roll again. Here every three is a doubling (on a logarithmic scale) but linear fractions between doublings are included.

This can be done at any ratio (using different sided dice). It should be based on the attribute that affects the simulation at the slowest rate to avoid some attributes using fractions or to the level of precision you wish to track. If this model is to be interactive and used by people doing these calculations, as in a game, learning tool, or simulation, then avoiding things like fractions are important. Each small additional step required, adds up as the calculations are done repeatedly throughout a session.

Prior to my work on this dissertation, I have implemented these different scales in hundreds of tabletop roleplaying sessions with success, as indicated by the observed easy of use and engagement of the players. However, a typical tabletop roleplaying session lasts several hours, involves half a dozen experienced players, each playing one character, and the sessions continue from week to week with the same players using the same characters. Under those conditions, more detail is needed to track the gradual changes a character undergoes over time. This would incorporate more of the details form the reviewed research.

However, this level of detail would not have been manageable for the active-shooter simulations which lasted about one hour each, involved up to two dozen players, most with no experience at roleplaying, most players portrayed multiple characters, and each session was started again a new with different players or characters. Since the data generated was really close to the real world data, the extra detail was not necessary. Detail was only added as needed, as was the case for study2 with basic attributes.

For categories or types of attributes to use, there is great variety among existing tabletop roleplaying systems. The focus for the active-shooter simulations was on a minimum number to keep the complexity low. Overly complicated characters would not have been appropriate.

One obvious difference between people is their size and strength. There is a correlation with size and strength but there is a lot of variation between the two. Without adding too much complexity, "build" is the attribute used to reflect size and strength. It is based on research by Mital & Kumar (1998).

Analyzing the Mital & Kumar (1998) data, revealed that absolute strength levels also follow a logarithmic scale based on standard deviations from the norm. The scale was approximately every four deviations was a doubling in absolute strength. However, a doubling in absolute strength is not required to affect the odds of succeeding at strength related tasks significantly.

Build is used to determine the ability to force open stuck doors, grapple, and can be used to determine absolute amount of weight that can be lifted but at a 1/4th scale. It can also be used to determine the size the target is for purposes of others shooting at them but here on a 1/8th scale. These ratios are gathered from Mital & Kumar (1998) for strength and size ratios. The impact on opening stuck doors and grappling initially came from my experience with existing tabletop roleplaying games and over twenty years with combat sports and strength training, both of which have weight classes. The affect the build attribute had on the simulation was confirmed as appropriate by the South Carolina

State Active-Shooter Training Program when they observed the simulation. It produced good results for the tabletop roleplaying active-shooter simulations. If there had been any perceived issues, adjustments to the scale could have been made.

Another way people can vary that impacts their chance of success at many tasks in an active-shooter event is their coordination. For this the attribute “action” is used as a modifier to physical tasks that do not rely mostly on size or strength, in which case the build attribute would be used. Physical skill acquisition and performance also follows a logarithmic scale (Chung et al. 2009; Eccles & Feltovich, 2008; Kanfer & Ackerman, 1989; Newell, 1991; Ward et al. 2004). Therefore, they were directly translated to the tabletop roleplaying structure, although simplified through this action attribute.

“Mind” is the attribute that reflects general intelligence (Lubinski, 2004; Schmidt, et al., 1988; Undheim & Gustafsson, 1987). Although this can be broken down into multiple sub-attributes, general intelligence accounts for half of all the observed variations between people (Kane & Engle 2002). To have the greatest affect with minimum complexity sub-attributes were not introduced. If the simulation data had required more precision then adding sub-attributes would have been considered. When personality attributes were added, the term mind was replaced with “intellect” and this included the personality trait of “openness” due to their close relation (Ashton, Lee, Vernon, & Jang. 2000). This attribute is used to figure things out and deal with complexity however, for the purposes of the simulation it was primarily used to determine how perceptive an individual was of their surroundings with differences in the physical aspects of the senses (such as the optic lens) not taken into account here.

Outside general intelligence, personality has a large impact on behavior (Schmidt, et al., 1988). Attributes based on the established five-factor model of personality traits were used to reflect this (Ashton et al., 2000; Mount & Barrick, 1998; Schmidt & Hunter, 2004; Zillig et al., 2002). Here the names of the attributes were selected based on sub-traits or definitions that would most likely reflect how they might be used in an active-shooter event simulation. Intellect to include openness has already been covered. The other four personality traits are reflected in the following attributes: “outgoing” for extraversion, “stable” to reflect negative neurotic, “compassion” to reflect agreeableness, and “dutiful” to reflect consciousness.

Proving this tabletop roleplaying structure was a valid means to simulate active-shooter events and superior to current computational models required multiple tests.

Testing the validity of this tabletop roleplaying structure as a simulation for active-shooter events required comparing the data it generated and the data generated from a computational model of the same event to real world data. It also required recreating a particular real world active-shooter event and comparing the data generated to the real world data from that event. To test the validity of changes made to the structure required running the tabletop roleplaying simulation with and without the changes, then comparing the results to the real world data to see which produced data closer to the real event.

For this dissertation to conduct this necessary testing, I ran two different studies using this tabletop roleplaying structure. For these studies, I ran multiple groups of individuals through tabletop roleplaying simulations of active-shooter events. In these simulations, the human participants each portrayed individuals such as teachers, students, police officers, or the shooter. A session was one simulation of an active-shooter event. It started with the shooter entering the school and ended when the shooter was stopped.

These sessions were in two separate categories. The first will be referred to as study1. It duplicated the fictional school in Anklam, et al. (2015). The purpose was to compare the data collected from the tabletop roleplaying to the computational model AnyLogic® ran by Anklam, et al. (2015) of the same fictional school with the same conditions. Then compare both to the data presented in Anklam, et al. (2015) of the averages of data collected from sixty-six active-shooter events over a five-year period. There were seventeen sessions of approximately an hour long each in study1.

The second category of sessions will be referred to as study2. It simulated the real world active-shooter event that took place at Sandy Hook Elementary School on December 14, 2012. The purpose was to compare the data collected from the tabletop roleplaying simulation to the real world data. Study2 ran some sessions with different modifications to the tabletop roleplaying structure to see if they improved the simulation by producing data more closely matching the real world data. The purpose in study2 was also to quantify more values and further define the structure so more could be implemented into computational models to improve their performance. There were ten sessions of approximately an hour long each in study2.

For these tabletop roleplaying simulations of active-shooter events, the term “moderator” is used to refer to the individual overseeing the simulation, as it best defines this role during these sessions; encourage the players as much as possible to drive the simulation and determine what happens. I was the moderator of all the sessions in both studies. All the other participants were undergraduate college students. They are referred to as players.

None of the players had police or active-shooter training. Less than one player per session had roleplaying game experience, this had no noticeable impact. The nature of the simulation was much different from games those players had participated in; it was much more narrowly focused on the event rather than long-term character development or social interactions. No other demographics were tracked or recorded because they were not deemed relevant. The only concern was they were humans rather than AI. They were actors. They portrayed characters and made decisions based on the characters' knowledge and goals, not their own. The players were just replacing the role of AI for the human agents in the simulation.

The players were told it was a simulation of an active-shooter event but not which one. There were different groups of twelve to twenty-four participants each. Roles were randomly assigned.

For both studies, some of the roles consisted of controlling multiple individual characters. When this was necessary all the characters controlled by one player would be in the same room or adjacent rooms and be similar roles. Classrooms where examples of this; one player had to portray the teacher and most or all of the students. In study2, some players even had to control multiple classrooms with each teacher and student having their own marker. The role of shooter never involved controlling multiple characters.

A study including hundreds of human participants each at their own table would not be feasible to manage and coordinate. However, this is unnecessary. Players controlled multiple individuals in the same room, it was not necessary to have 15 people all say, "I will follow everyone else out the door."

The moderator sets the scenario and all the details, many of which are kept from the players. Each player takes on the role of one or more characters in the simulation. The character they portray will determine their position in the simulation, the knowledge they have, their goals and motivation, and protocols they are to follow. All these things may change during a session.

Before a session began, the moderator had to set up the session and assign the players to the various character roles in the simulation. Then the moderator had to move the simulation forward by asking players what their characters do next; record all the actions and times; answer questions players had about the simulation rules, world, and information their characters had. The moderator also had to determine when dice rolls are needed, the odds of success for actions, and explain to the players the results of any actions their characters took.

These tasks were defined in part by being a tabletop roleplaying session but most were defined by the structure’s rules, see Table 2 and Table 3. Matters that were not explicitly addressed by the structure relied upon my experience of over thirty years, thousands of hours running hundreds of tabletop roleplaying sessions, and tens of thousands of hours preparing those sessions and designing tabletop roleplaying structures most with the intent to accurately simulate the real world. Rulings were made to adhere to the existing structure as much as possible. They were added to the structure if they seemed likely to come up again.

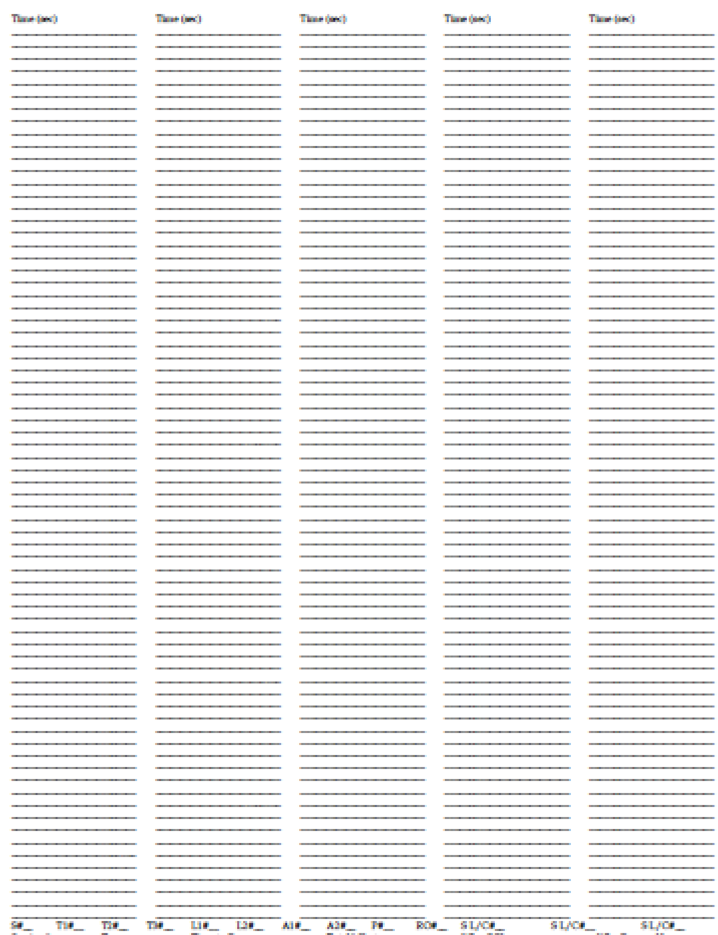
For these tabletop roleplaying active-shooter event simulations, six identical maps of the school were drawn on three-foot by four-foot grid surfaces. These maps were placed on different tables or separated by dividers. This was to separate players from one another so one would not know what was going on at a far off location. Only if characters migrated from distant sections of the map to their section did they become aware of the other character's location and actions. The characters are not able to see around hallway corners for example so the player portraying these characters had that information hidden from them.

Each map consisted of a grid of one-inch squares. Each square represented a ten-foot-by-ten-foot section of the school. The same identical floor plan was drawn on each map. Lines were draw with black markers onto the maps for the outside walls and all the interior walls to create all the rooms and locations. Also drawn were doors showing which way they opened and whether they were currently open or closed. The marks made on the maps could be wiped off and redrawn to make changes such as updating doors being open or closed. Also drawn on the map were the locations of windows, fire alarms, and fire extinguishers. Furniture was drawn when needed but initially all the desks and chairs were not indicated since most were initially occupied and their location started out being the same as the individual sitting there.

Once the maps were established there had to be a way to represent the people. The military uses aggregate-level simulations for larger scales, where multiple units are given a single representation; entity-level simulations are for smaller scales, where each individual is given its own representation (Page & Smith 1998). The scale of these active-shooter events warranted each individual being represented.

Numbered half-inch square cutouts were used to represent each individual. Thick construction paper was used to make them easier to pick up or move on the map. Every individual on the campus of the school during the active-shoot event was represented. This included the shooter, the administrators, the resource officer when present, the teachers and every single student, and the other faculty and staff members, and the police.

The duration of a session went from the time when the shooter first stepped on campus until the shooter was neutralized by being killed or fully restrained. Figure 1 shows the record sheet used by the moderator to keep track of time and record everything that took place during the simulation.



Time (sec) Time (sec) Time (sec) Time (sec) Time (sec)

S#__ T1#__ T2#__ T3#__ L1#__ L2#__ A1#__ A2#__ P#__ RO#__ S L/C#__ S L/C#__ S L/C#__

Session#______ Type______ Time to Engage______ Total# Shot______ Who CC?______ Who Engaged?______

Figure 1. Record sheet

Study1

The first study simulated active-shooter events identical to the ones in Anklam, et al. (2015). The same fictional school map and agent conditions were used. Anklam, et al. (2015) ran their simulations in the AnyLogic® computational model. The goal was to compare the results from both the tabletop roleplaying and the computation model to data from an aggregate of real world events.

For the first study the data collected from these events included the number of individuals shot and the duration of the event. This data along with the data generated from the agent-based computational model AnyLogic® was compared to the actual data gathered from real active-shooter-events. AnyLogic® is widely used in industry and academia and is the model used in Anklam, et al. (2015). The real world data was collected from 66 active-shooter events over a 5-year period and the AnyLogic® data was collected from running the simulation 50 times. Both of these results were published in Anklam, et al. (2015). The roleplaying data was collected from my experiments of 17 roleplaying sessions duplicating the simulations run on the AnyLogic® system but with humans portraying the roles of the individuals in the simulation instead of AI agents. The simulated school was not an actual school. The floor plan is in Figure 2.

All the parameters in study1 were set to match the conditions of the scenarios ran in AnyLogic® by Anklam, et al. (2015).

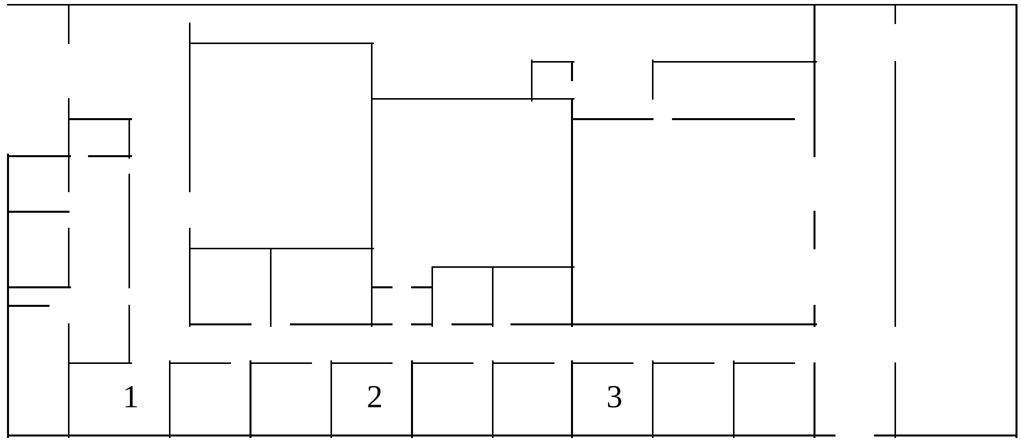


Figure 2. Study1 map

Study1 session setup

1 Determine scenario type

no RO (resource Officer), no CC (conceal carry employee)

no RO (resource Officer), CC (conceal carry employee)

RO (resource Officer), no CC (conceal carry employee)

RO (resource Officer), CC (conceal carry employee)

2 If concealed carry, d6 to determine who

1-2 class (another d6):

1-2 room1

3-4 room2

5-6 room3

3-4 cafeteria (another d6):

1-2 lunch duty teacher1

3-4 lunch duty teacher2

5-6 lunch duty administrator2

5-6 office (another d6):

1-2 secretary

4-6 principle, administrator1

3 Assign roles by randomly drawing

#12: Shooter (must have 1)

#9: RO (if scenario type includes, must have 1)

#1, #2, & #3: Teacher, classroom (must have 3, one for rooms 1, 2, & 3)

#4 & #5: Teacher, lunch duty (must have at least 1 for two lunch duty teachers)

#6: Administrator2, lunch duty (may have 1, else include with lunch duty teacher)

#7: Administrator1, office (must have at least 1 for two in office)

#8 Police Officers (must have at least 1 to control all 10 officers)

Students (after all above roles filled, additional players, d6 for location):

1 classroom1

2 classrom2

3 classrom3

4-6 cafeteria

Notes: Police arrive 5-10 (d6+4) minutes after being reported.

Study1 roles

Role: Shooter

Start Position: Start at front entrance.

Protocol: Kill as many as possible in minimum time.

Items: Pistol (12 rounds, 3 clips total), Rifle (20 rounds, 3 clips total)

Role: Resource Officer #9

Start Position: Outside doors of gym.

Protocol: Go to ready position in hall. Then go directly to sounds of threat. Call district office on radio. Act to mitigate threats once detected, defuse or confine threats.

Items: Radio, Pistol (12 rounds, 2 clips total) in holster, Orange Vest.

Role: 3 Police Officers, rifles #8

Start Position: Arrive minutes after reported. Enter main entrance with 10 officers.

Protocol: Tactically (crouched weapons ready, slice pie, cover all angles) go directly to sounds of threat. Act to mitigate threats once detected, defuse or confine threats. If possible give commands to threat, respond with force if necessary.

Items: Pistol (12 rounds, 3 clips total), Rifle (20 rounds, 3 clips total)

Role: 7 Police Officers, shotgun

Start Position: Arrive minutes after reported. Enter main entrance with 10 officers.

Protocol: Tactically (crouched weapons ready, slice pie, cover all angles) go directly to sounds of threat. Act to mitigate threats once detected, defuse or confine threats. If possible give commands to threat, respond with force if necessary.

Items: Pistol (12 rounds, 3 clips total), Shotgun (7 rounds, used to breech doors)

Role: Teacher, classroom1 #1

Start Position: In classroom1 by whiteboard.

Protocols

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: Teacher, classroom2 #2

Start Position: In classroom1 by whiteboard.

Protocols

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: Teacher, classroom3 #3

Start Position: In classroom1 by whiteboard.

Protocols

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: Teacher, lunch duty1 #4

Start Position: In cafeteria corner.

Protocols

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Students leave single file to Cafeteria Lobby. Leave all items behind. Teacher follows, lock all doors, sit on floor against walls away from doors, out of sight.

Role: Administrator, lunch duty #6

Start Position: In cafeteria roaming.

Protocols

Evacuate: Students leave single file out the building. Leave all items behind. Administrator is last, checks doors.

Lockdown: Students leave single file to Cafeteria Lobby. Leave all items behind. Teacher follows, lock all doors, admin checks doors, all sit on floor against walls away from doors, out of sight. Call district office on radio.

Items: Radio.

Role: Administrator, office #7

Start Position: In office.

Protocols

Evacuate: Exit building. Leave all items behind. Lock doors.

Lockdown: Shelter-in-Place, lock door, get out of sight under desk. Call district office on radio.

Items: Radio.

Role: Teacher, classroom, conceal carry

Start Position: In classroom by whiteboard.

Protocols

Evacuate: Students leave single file. Leave all items behind. Teacher is last, locks doors.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks. Get weapon, don vest. Only respond in a defensive posture to the threat. Stay with and protect students. Diffuse or confine threat.

Items: Pistol (12 rounds, 2 clips total) in locked box with orange vest in locked desk drawer.

Role: Teacher, lunch duty, conceal carry

Start Position: In cafeteria corner.

Protocols

Evacuate: Students leave single file out the building. Leave all items behind. Teacher follows, locks doors.

Lockdown: Students leave single file to Cafeteria Lobby. Leave all items behind. Teacher follows, lock all doors, sit on floor against walls away from doors, out of sight. Only respond in a defensive posture to the threat. Stay with and protect students. Diffuse or confine threat.

Items: Pistol (12 rounds, 2 clips total) in holster, Orange Vest, (and if Administrator) Radio.

Role: Administrator, lunch duty, conceal carry #6

Start Position: In cafeteria roaming.

Protocols

Evacuate: Students leave single file out the building. Leave all items behind. Administrator is last, checks doors.

Lockdown: Students leave single file to Cafeteria Lobby. Leave all items behind. Teacher follows, lock all doors, admin checks doors, all sit on floor against walls away from doors, out of sight. Call district office on radio. Only respond in a defensive posture to the threat. Stay with and protect students. Diffuse or confine threat.

Items: Radio, Pistol (12 rounds, 2 clips total) in holster, Orange Vest.

Role: Administrator, office, conceal carry #7

Start Position: In office.

Protocols

Evacuate: Exit building. Leave all items behind. Locks door.

Lockdown: Shelter-in-Place, lock door, get out of sight under desk. Call district office on radio. Stay in office. Get weapon, don vest. Only respond in a defensive posture to the threat. Diffuse or confine threat.

Items: Radio, Pistol (12 rounds, 2 clips total) in holster, Orange Vest.

Role: Student, class

Start Position: In classroom in desk.

Protocol: Follow teacher instructions.

Role: Student, lunch

Start Position: In cafeteria at table.

Protocol: Follow teacher instructions.

Table 4: Study1 session types

Session	Type
1	no RO, no CC
2	no RO, no CC
3	no RO, no CC
4	RO, no CC
5	RO, no CC
6	RO, no CC
7	no RO, CC
8	no RO, CC
9	no RO, CC
10	RO, CC
11	RO, CC
12	RO, CC
13	no RO, no CC
14	no RO, no CC
15	no RO, CC
16	no RO, CC
17	RO, no CC

Study2

The second study simulated an actual active-shooter event and compared results to the real world data of that one event. Different versions of tabletop roleplaying simulations were run to compare the results from each version to the real world data to see which versions were more accurate.

The setup for study2 required the following steps:

Assign roles by randomly drawing:

#1 Shooter (must have 1)

#2 Police Officers (at least 1 to control all 4 officers)

#3 Meeting Room (at least 1 to control all 3 in meeting room)

#4 Main Office (at least 1 to control all 3 in meeting room)

#5 Other Staff Members (at least 1 to control any that may be encountered)

#6classrooms 8, 10, & 7 (at least 1 to control all in these rooms)

#7classrooms 5 & 7 (at least 1 to control all in these rooms)

#8classrooms 3 & 6 (1 to control all in these rooms, may combine w/#7)

#9classrooms 1, 53, 54, & 56 (at least 1 to control all in these rooms)

#10classrooms 50 & 52 (least 1 to control all in these rooms)

#11classrooms 48, 49 & 51 (1 to control all in these rooms, may combine w/#10)

#12classrooms 19, 21, 23, & 25 (at least 1 to control all in these rooms)

#13classrooms 42 & 46 (1 to control all in these rooms, may combine w/#10)

#14classrooms 26, 28, 30, 32, & 34 (at least 1 to control all in these rooms)

#15classrooms 62, 63, & 64 (must have at least 1 to control all in these rooms)

Need at least 12 participants, participants beyond the first 15 can be assigned to assist roles with multiple rooms.

Notes: Police arrive (d6 times 15 seconds + 3 minutes) after being reported.

Study2 was based on an actual event and there was a lot more detailed information than in study1. All the parameters in study2 were based on information from the FBI about this event. Because there were more details on the individuals in each room, this meant there would be more characters being portrayed by approximately the same number of players as in study1.

In study2, the square cutouts representing people were color coated by grade: white for special education teachers, teacher-aids, and students in rooms #3 and #6 portrayed by player #8; pink for preschool teachers, teacher-aids, and students in rooms #53 and #56 portrayed by player #9; red for kindergarten teachers, teacher-aids, and students in rooms #1 and #54 also portrayed by player #9; orange for first grade teachers, teacher-aids, and students in rooms #8, #10, and #12 portrayed by player #6 and rooms #50 and #52 portrayed by player #10; yellow for second grade teachers, teacher-aids, and students in rooms #5 and #7 portrayed by player #7 and rooms #19, #21, and #23 portrayed by player #12; green for third grade teachers and students in rooms #25 also portrayed by player #12 and rooms #26, #28, #30, #32, and #34 portrayed by player #14; blue for fourth grade teachers and students in rooms #42 and #46 portrayed by player #13 and the outside portable rooms #62, #63, and #64 portrayed by player #15; purple for Spanish language in room #48, computer lab in room #49, and art in room #51, all portrayed by player #11, also purple for the principle , administrator, and councilor in the meeting room portrayed by player #3; the secretary and administrator in the main office portrayed by player #4; and all the other staff members that might be encountered such as maintenance, kitchen staff, and janitorial staff including the janitor in the hall at the beginning of the event, all portrayed by player #5. The shooter was represented with a half inch diameter circle with the number 1 on it and was portrayed by player #1. The four police officers were represented by blue half inch cube blocks and were portrayed by player #2. All of this is also listed in Table 5.

Table 5: Study2 map representations

Player Number	Role	Map Representation	Starting Position
#1	shooter	circle	front of school
#2	police	blue cubes	not on map
#3	prin., councilor, admin	purple squares	meeting room
#4	admin&secretary	purple squares	main office
#5	other staff members	purple squares	hall
#6	1st grade teachers,aids,&students	orange squares	rooms 8, 9, & 10
#7	2nd grade teachers,aids,&students	yellow squares	rooms 5 & 7
#8	Special Education teachers,aids,&students	white squares	rooms 3 & 6
#9	preschool&kindergarten teachers,aids,& students	pink&red squares	rooms 1, 53, 54, & 56
#10	1st grade teachers,aids,&students	orange squares	rooms 50 & 52
#11	Spanish,Art,&Comp. teachers&students	purple squares	rooms 48, 49 & 51
#12	2nd&3rd grade teachers,aids,&students	yellow&green squares	rooms 19, 21, 23, & 25
#13	4th grade teachers&students	blue squares	rooms 42 & 46
#14	3rd grade teachers,aids,&students	green squares	rooms 26, 28, 30, 32, & 34
#15	4th grade teachers&students	blue squares	rooms 62, 63, & 64

Each room on the map had a number, see Figure 3. Each square had a number corresponding to a number on the map. This was the room those characters started in. Each square also had a letter to distinguish the individuals within a classroom or other starting area. The adults were given capital letters and taped to glass beads to be easier to identify and move. The characters and their starting rooms were grouped together based on how close they were on the map but also when possible by grade level. This was to make the task of portraying multiple characters in multiple rooms easier for the players.

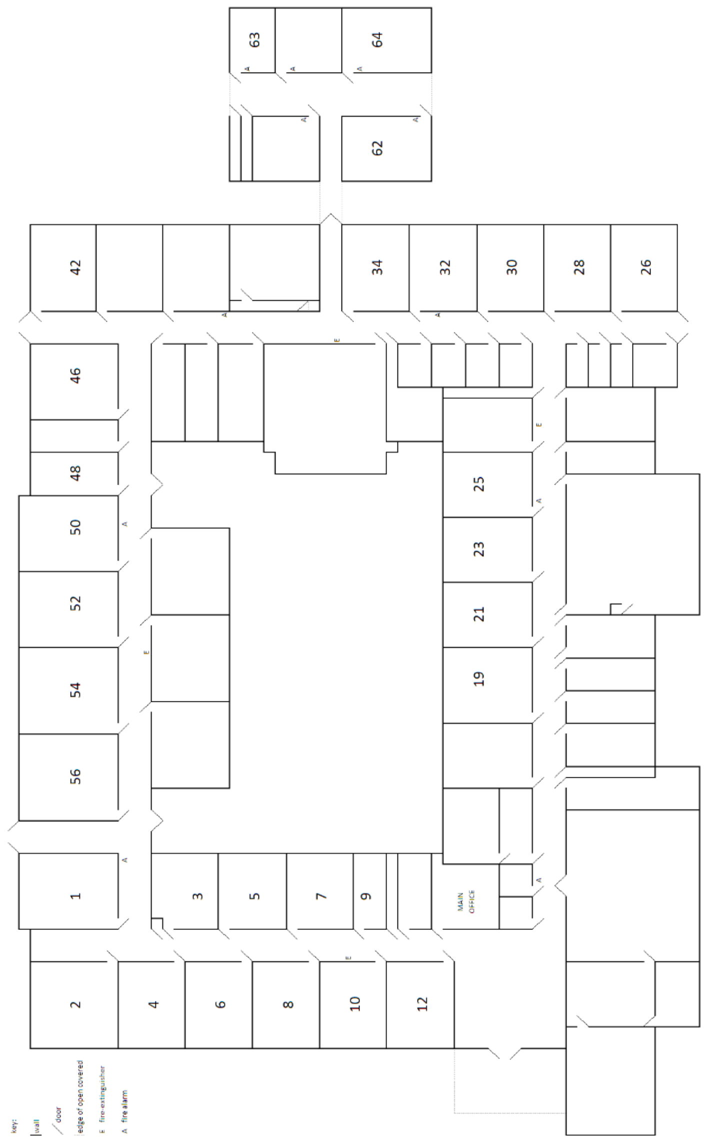


Figure 3. Study2 map

The following descriptions were handed out to the players. Each player got only one description. Each description lists the player number (randomly determined by drawing blindly from a bag), name of the character role, start position on the map, and protocol stating what they should do. Some roles also list items the character has with them.

#1 Shooter

Role: Shooter

Start Position: Start at front entrance.

Protocol: You are an adult. You live with your mother. She left you alone for two and a half days, getting home late last night. This morning you shot her in her bed and left the rifle. Then you drove to your old school to quickly kill as many as possible before you end it all.

Items: Hat, sunglasses, 2 Pistols (15 rounds each, 4 extra clips each, not interchangeable), Rifle (2x30round clips taped together, plus 8x20round clips), In car: Shotgun (10 rounds, plus 4 extra clips)

#2 Police

Role: Police Officer car1, driver, rifle

Start Position: Arrive minutes after reported at rear of building.

Protocol: Tactically (crouched weapons ready, slice pie, cover all angles) go directly to sounds of threat. Act to mitigate threats once detected, defuse or confine threats. If possible give commands to threat, respond with force if necessary.

Items: Pistol (12 rounds, 3 clips total), Rifle (20 rounds, 3 clips total)

#2 Police, continued

Role: Police Officer car2, driver, rifle

Start Position: Arrive minutes after reported at front of building.

Protocol: Tactically (crouched weapons ready, slice pie, cover all angles) go directly to sounds of threat. Act to mitigate threats once detected, defuse or confine threats. If possible give commands to threat, respond with force if necessary.

Items: Pistol (12 rounds, 3 clips total), Rifle (20 rounds, 3 clips total)

Role: Police Officer car3, driver, rifle

Start Position: Arrive minutes after reported at front of building.

Protocol: Tactically (crouched weapons ready, slice pie, cover all angles) go directly to sounds of threat. Act to mitigate threats once detected, defuse or confine threats. If possible give commands to threat, respond with force if necessary.

Items: Pistol (12 rounds, 3 clips total), Rifle (20 rounds, 3 clips total)

Role: Police Officer car3, passenger, shotgun

Start Position: Arrive minutes after reported at front of building.

Protocol: Tactically (crouched weapons ready, slice pie, cover all angles) go directly to sounds of threat. Act to mitigate threats once detected, defuse or confine threats. If possible give commands to threat, respond with force if necessary.

Items: Pistol (12 rounds, 3 clips total), Shotgun (7 rounds, used to breech doors)

#3 Meeting Room

Role: Principle

Start Position: Meeting Room #9.

Protocols:

Evacuate: Exit building. Leave all items behind. Lock doors.

Lockdown: Shelter-in-Place, lock door, get out of sight under desk.

Call district office on radio.

Items: Radio.

Role: Counselor

Start Position: Meeting Room #9.

Protocols:

Evacuate: Exit building. Leave all items behind. Lock doors.

Lockdown: Shelter-in-Place, lock door, get out of sight under desk.

Role: Administrator

Start Position: Meeting Room #9.

Protocols:

Evacuate: Exit building. Leave all items behind. Lock doors.

Lockdown: Shelter-in-Place, lock door, get out of sight under desk.

Call district office on radio.

Items: Radio.

#4 Main Office

Role: Administrator

Start Position: Main Office.

Protocols:

Evacuate: Exit building. Leave all items behind. Lock doors.

Lockdown: Shelter-in-Place, lock door, get out of sight under desk.

Call district office on radio.

Items: Radio.

Role: Staff Member

Start Position: Main Office.

Protocols:

Evacuate: Exit building. Leave all items behind. Lock doors.

Lockdown: Shelter-in-Place, lock door, get out of sight under desk.

#5 Other Staff Members

Role: Other Staff Members

Start Position: 1 in Hall by classes #2 & #4.

Protocols:

Evacuate: Exit building. Leave all items behind. Lock doors.

Lockdown: Shelter-in-Place, lock door, get out of sight under desk.

Items: Radio (only if custodian or maintenance).

#6 classrooms 8, 10, & 12

Role: Teacher, classroom

Start Position: In classroom by whiteboard.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: Teacher-Aid/Counselor, classroom

Start Position: In back of classroom.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: students, classroom

Start Position: At desks in middle of classroom.

Protocol: Follow teacher’s instructions.

#7 classrooms 5 & 7

Role: Teacher, classroom

Start Position: In classroom by whiteboard.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: students, classroom

Start Position: At desks in middle of classroom.

Protocol: Follow teacher's instructions.

#8 classrooms 3 & 6

Role: Teacher, classroom

Start Position: In classroom by whiteboard.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: Teacher-Aid/Counselor, classroom

Start Position: In back of classroom.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: students, classroom

Start Position: At desks in middle of classroom.

Protocol: Follow teacher’s instructions.

#9 classrooms 1, 53, 54, & 56

Role: Teacher, classroom

Start Position: In classroom by whiteboard.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: Teacher-Aid/Counselor, classroom

Start Position: In back of classroom.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: students, classroom

Start Position: At desks in middle of classroom.

Protocol: Follow teacher’s instructions.

#10 classrooms 50 & 52

Role: Teacher, classroom

Start Position: In classroom by whiteboard.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: Teacher-Aid/Counselor, classroom

Start Position: In back of classroom.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: students, classroom

Start Position: At desks in middle of classroom.

Protocol: Follow teacher’s instructions.

#11 classrooms 48, 49 & 51

Role: Teacher, classroom

Start Position: In classroom by whiteboard.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: students, classroom

Start Position: At desks in middle of classroom.

Protocol: Follow teacher's instructions.

#12 classrooms 19, 21, 23, & 25

Role: Teacher, classroom

Start Position: In classroom by whiteboard.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: students, classroom

Start Position: At desks in middle of classroom.

Protocol: Follow teacher's instructions.

#13 classrooms 42 & 46

Role: Teacher, classroom

Start Position: In classroom by whiteboard.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: students, classroom

Start Position: At desks in middle of classroom.

Protocol: Follow teacher’s instructions.

#14 classrooms 26, 28, 30, 32, & 34

Role: Teacher, classroom

Start Position: In classroom by whiteboard.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: students, classroom

Start Position: At desks in middle of classroom.

Protocol: Follow teacher’s instructions.

#15 classrooms 62, 63, & 64

Role: Teacher, classroom

Start Position: In classroom by whiteboard.

Protocols:

Evacuate: Students leave single file out the building. Leave all items behind. Teacher is last, locks door.

Lockdown: Shelter-in-Place, lock door, get all out of sight. All get under desks.

Role: students, classroom

Start Position: At desks in middle of classroom.

Protocol: Follow teacher's instructions.

The map for study2 is based on the map of Sandy Hook Elementary School seen in Figure 3. For study2, the simulation attempted to duplicate the real world active-shooter event of Sandy Hook. This event was chosen based on the availability of the data from the FBI. The six identical maps where divided by the four hallways, plus one for the outside portables, plus one for the shooter when they were not in sight of any of the other characters.

Versions were run both with and without attributes for the human characters portrayed in the simulation. Four sessions were ran without attributes, six with attributes. These included indication of the character being male or female, an attribute for the size and strength of the character, another for hand-eye coordination and athleticism, and another for general intelligence and cognitive ability.

There were also four attributes for personality traits. These were used in four of the six sessions with attributes. These personality attributes were based on the big five model (Zillig, et al., 2002). Each attribute corresponded to one of the five personality traits. The one not represented, openness, was considered part of the intellect/cognitive attribute since it is closely related to general intelligence.

An explanation was given to all the participants of each attribute as well as how it would impact the simulation. Each attribute was given a numerical value to affect the odds of success involving that attribute. For example a character with a large build score would have an increased chance of succeeding at pushing open a stuck door.

The moderator would call for a die roll adding a personality attribute when the character attempted a task related to it. Outgoing was used when a character engaged in social interaction with other characters with success increasing the positive feelings other characters had toward them and failure increasing negative feelings. Stable attribute die rolls were called when the character had to overcome fear or stressful situations to attempt some action, such as grab the shooter's gun with failure giving a penalty to the action if the character still attempted them. Compassion attribute die rolls were required if the character tried to take some action that the character knew would put others in harm with failure acting as a penalty to the action if they still attempted it. Dutiful attribute die rolls were called when the character attempted actions that went against their responsibilities with failures acting as penalties to the actions if they still attempted them. Often failure was enough to causes the player to rethink attempting an action. Some situations involved multiple personality attributes in which case they would both be added to the die roll. For example trying to attack the shooter while being unarmed in order to save student lives would require a die roll adding both stable and compassion.

The values of the attributes were randomly assigned to each character based on the odds of deviation from the norm of a particular quantified score. In a spreadsheet, the random function produced a decimal value from zero to less than one. Then the inverse normal cumulative distribution function was used with the probability generated by the random function, with a norm equaling zero and one standard deviation equaling one. This produced, in standard deviations, the odds of a particular randomly generated value.

Whether the character was an adult male or female was taken into account for the build attribute with +2 applied for adult males and -2 applied to adult females. This was based on the absolute value of males being twice as strong as females and four deviations representing a doubling in strength (Mital & Kumar, 1998). Since faculty members would have been college educated and college educated populations have IQ scores one standard deviation above the general population (Lubinski, 2004), +1 was added to their scores in mind or intellect, depending on which was used in the session. For manageability, a single set of values were used for all the students of a particular classroom, average values for all attributes were assigned based on the students' age/grade of a particular classroom (Flynn, 1984).

Below are the randomly generated attribute scores for all the characters in the study2 simulation sessions.

Study2: Session Attributes Scores

Study2 Sessions 1, 2, 3, & 4 were without Attributes Scores

Study2 Session5 Attribute (without Personality) Scores

#1Session5	mind	action	build	m/f
shooter	0	0	2	m

#2Session5	mind	action	build	m/f
car2	2	0	3	m
car2driver	-1	1	0	m
car2passanger	2	-1	3	m

#3Session5	mind	action	build	m/f
Principle	2	1	-2	f
Counselor	4	0	-3	f
Administrator	2	0	-2	f

#4Session5	mind	action	build	m/f
Administrator	2	-1	1	f
Staff Member	1	0	-2	f

#5Session5	mind	action	build	m/f
Staff Member1	0	1	-2	f
Staff Member2	-3	0	-2	f
Staff Member3	0	0	-3	f
Staff Member4	-1	0	-2	f
Staff Member5	-2	-1	-2	f
Staff Member6	0	1	-2	f
Staff Member7	2	0	4	m
Staff Member8	-7	-2	-3	f
Staff Member9	-2	2	-2	f

#6Session5	mind	action	build	m/f
Teacher8rm	4	-1	-1	f
TA8rm	3	1	-3	f
Teacher10rm	-1	0	-3	f
TA10rm	0	0	-3	f
Teacher12rm	2	-1	-2	f
TA12rm	0	0	0	f

#7Session5	mind	action	build	m/f
Teacher5rm	0	-1	-3	f
Teacher7rm	4	0	0	f

#8Session5	mind	action	build	m/f
Teacher3rm	0	2	-1	f
TA3rm	-1	0	1	m
Teacher6rm	0	2	-3	f
TA6rm	4	1	2	m

#9Session5	mind	action	build	m/f
Teacher1rm	-1	-1	-2	f
TA1rm	0	0	-1	f
Teacher53rm	1	1	-2	f
TA53rm	1	1	3	m
Teacher54rm	1	1	0	f
TA54rm	-1	1	-2	f
Teacher56rm	0	0	-1	f
TA56rm	0	0	0	f

#10Session5	mind	action	build	m/f
Teacher50rm	3	0	-2	f
TA50rm	4	-1	1	m
Teacher52rm	-1	-1	-2	f
TA52rm	-1	0	-2	f

#11Session5	mind	action	build	m/f
Teacher48rm	2	0	-4	f
Teacher49rm	1	1	-2	f
Teacher51rm	4	0	0	f

#12Session5	mind	action	build	m/f
Teacher19rm	1	-1	-2	f
Teacher21rm	4	0	-2	f
Teacher23rm	2	-1	1	m
Teacher25rm	3	1	-3	f

#13Session5	mind	action	build	m/f
Teacher42rm	4	0	-1	f
Teacher46rm	-1	0	-1	f

#14Session5	mind	action	build	m/f
Teacher26rm	0	-1	-4	f
Teacher28rm	-1	0	-4	f
Teacher30rm	1	-1	-2	f
Teacher32rm	0	-1	-1	f
Teacher34rm	1	-1	-2	f

#15Session5	mind	action	build	m/f
Teacher62rm	3	-1	3	m
Teacher63rm	2	-2	-2	f
Teacher64rm	4	-1	-2	f

Study2 Session6 Attributes (without Personality) Scores

#1Session6	mind	action	build	m/f
shooter	0	0	2	m

#2Session6	mind	action	build	m/f
car1	-1	-1	-2	f
car2	1	0	2	m
car2driver	-1	-1	-2	f
car2passanger	2	-1	2	m

#3Session6	mind	action	build	m/f
Principle	4	-1	-4	f
Counselor	1	1	-3	f
Administrator	-1	-1	0	f

#4Session6	mind	action	build	m/f
Administrator	4	0	2	m
Staff Member	1	1	-3	f

#5Session6	mind	action	build	m/f
Staff Member1	-6	0	0	f
Staff Member2	0	0	-3	f
Staff Member3	0	-2	-3	f
Staff Member4	-1	-1	-2	f
Staff Member5	2	1	-4	f
Staff Member6	-1	-2	-1	f
Staff Member7	0	-1	-1	f
Staff Member8	-4	2	-3	f
Staff Member9	-1	0	2	m

#6Session6	mind	action	build	m/f
Teacher8rm	3	0	0	f
TA8rm	2	-3	-3	f
Teacher10rm	3	0	-4	f
TA10rm	3	0	0	f
Teacher12rm	-1	0	-3	f
TA12rm	1	0	-3	f

#7Session6	mind	action	build	m/f
Teacher5rm	0	1	-2	f
Teacher7rm	1	1	-1	f

#8Session6	mind	action	build	m/f
Teacher3rm	3	0	-2	f
TA3rm	4	1	-2	f
Teacher6rm	3	1	2	m
TA6rm1	0	-2	f	

#9Session6	mind	action	build	m/f
Teacher1rm	2	-3	-2	f
TA1rm	4	-1	-2	f
Teacher53rm	1	-1	-3	f
TA53rm	4	0	-3	f
Teacher54rm	2	0	-3	f
TA54rm	1	-1	-3	f
Teacher56rm	1	-2	1	m
TA56rm	-1	-1	0	f

#10Session6	mind	action	build	m/f
Teacher50rm	3	0	-1	f
TA50rm	6	-1	-1	f
Teacher52rm	0	0	-1	f
TA52rm	-1	-1	-2	f

#11Session6	mind	action	build	m/f
Teacher48rm	2	2	-2	f
Teacher49rm	4	-1	-3	f
Teacher51rm	3	1	-1	f

#12Session6	mind	action	build	m/f
Teacher19rm	1	-1	2	m
Teacher21rm	2	0	-2	f
Teacher23rm	1	0	-2	f
Teacher25rm	2	0	-1	f

#13Session6	mind	action	build	m/f
Teacher42rm	2	-2	-3	f
Teacher46rm	-1	-1	-3	f

#14Session6	mind	action	build	m/f
Teacher26rm	2	2	-1	f
Teacher28rm	3	1	2	m
Teacher30rm	3	-1	1	m
Teacher32rm	-1	1	-2	f
Teacher34rm	3	-1	3	m

#15Session6	mind	action	build	m/f
Teacher62rm	0	1	0	f
Teacher63rm	1	-1	-3	f
Teacher64rm	1	-1	-2	f

Study2 Session7 Attributes (with Personality) Scores

#1Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
shooter	m	2	0	-2	-8	-8	-8	-4

#2Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
car1	m	1	1	3	2	0	1	1
car2	m	2	0	0	2	3	0	0
car3driver	m	2	0	-1	-1	0	1	-1
car3passanger	m	2	1	-1	1	-1	-1	2

#3Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
Principle	f	-3	1	2	5	2	1	0
Counselor	f	0	-2	-1	0	-1	-1	1
Administrator	f	-3	-2	3	2	3	3	-1

#4Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
Administrator	m	2	-1	4	0	2	1	7
Staff Member	f	-2	0	3	3	4	4	-1

#5Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
Staff Member1	f	-2	-1	-5	-1	0	-2	-2
Staff Member2	f	-3	1	-1	-1	-1	-4	-2
Staff Member3	f	-2	-1	-1	-3	-2	-3	-3
Staff Member4	m	2	0	-2	2	-3	-3	1
Staff Member5	f	-2	0	-2	-2	1	0	4
Staff Member6	f	-3	-2	2	-5	-4	-1	1
Staff Member7	f	-1	-2	-2	0	-2	-4	-5
Staff Member8	f	-2	1	0	1	-3	-1	-3
Staff Member9	f	-2	1	1	0	-7	-1	-2
Staff Member10	m	3	1	0	-1	-4	0	-2
Staff Member11	f	-3	0	-3	-1	1	1	-3
Staff Member12	f	-1	-1	1	0	-1	1	1
Staff Member13	f	-2	-2	1	-2	2	1	0
Staff Member14	f	-3	0	2	-2	1	0	5
Staff Member15	f	0	1	-4	0	-1	-2	-2

#6Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
8-Teacher	f	-3	0	1	4	3	1	3
8-TA	f	-1	1	5	5	2	0	6
8-students		-5	-3	-6	0	-6	0	-6
10-Teacher	f	-3	-1	-1	1	2	1	0
10-TA f		-2	-1	-1	2	4	3	0
10-students		-5	-3	-6	0	-6	0	-6
12-Teacher	f	-2	1	4	3	4	2	2
12-TA	f	-2	-2	0	0	0	4	1
12-students		-5	-3	-6	0	-6	0	-6

#7Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
5-Teacher	f	-3	0	0	2	-1	3	-1
5-students		-5	-3	-5	0	-5	0	-5
7-Teacher	f	-1	0	-1	2	0	1	4
7-students		-5	-3	-5	0	-5	0	-5

#8Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
3-Teacher	f	-2	-2	1	0	-1	4	5
3-TA	f	-3	0	4	-1	3	2	1
3-students		-4	-3	-8	0	-8	0	-8
6-Teacher	m	2	0	3	6	2	3	2
6-TA	f	-2	0	3	2	2	1	0
6-students		-6	-4	-11	0	-11	0	-11

#9Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
1-Teacher	f	-2	0	1	3	3	4	-1
1-TA	f	-3	-1	3	0	2	3	2
1-students		-6	-4	-7	0	-7	0	-7
53-Teacher	f	-1	0	3	0	2	3	2
53-TA	f	-1	1	2	5	-1	-1	2
53-students		-6	-4	-8	0	-8	0	-8
54-Teacher	f	-3	0	3	2	0	3	2
54-TA	f	-1	1	3	2	-1	0	1
54-students		-6	-4	-7	0	-7	0	-7
56-Teacher	f	-2	2	-1	1	0	3	5
56-TA	f	-3	1	2	-1	2	-1	2
56-students		-6	-4	-8	0	-8	0	-8

#10Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
50-Teacher	f	-2	-1	4	1	1	-1	3
50-TA	f	0	1	1	-1	3	4	0
50-students		-5	-3	-6	0	-6	0	-6
52-Teacher	f	-1	-1	4	4	2	2	6
52-TA	f	0	0	-1	3	1	-1	4
52-students		-5	-3	-6	0	-6	0	-6

#11Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
48-Teacher	f	-3	-1	2	3	2	1	-1
48-students		-5	-3	-5	0	-5	0	-5
49-Teacher	f	-1	0	1	3	3	4	2
49-students		-6	-4	-8	0	-8	0	-8
51-Teacher	f	-3	-1	-1	1	1	2	3
51-students		-4	-2	-3	0	-3	0	-3

#12Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
19-Teacher	f	-3	0	5	0	-1	2	2
19-students		-5	-3	-5	0	-5	0	-5
21-Teacher	f	-2	-1	0	2	2	3	-1
21-students		-5	-3	-5	0	-5	0	-5
23-Teacher	f	-1	0	3	5	-1	1	4
23-students		-5	-3	-5	0	-5	0	-5
25-Teacher	f	-2	-2	2	2	5	2	2
25-students		-4	-2	-4	0	-4	0	-4

#13Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
42-Teacher	f	-3	0	2	2	1	4	1
42-students		-4	-2	-3	0	-3	0	-3
46-Teacher	f	-1	1	5	3	6	4	4
46-students		-4	-2	-3	0	-3	0	-3

#14Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
26-Teacher	f	-3	2	3	-1	0	1	2
26-students		-4	-2	-4	0	-4	0	-4
28-Teacher	f	-2	0	4	1	1	3	5
28-students		-4	-2	-4	0	-4	0	-4
30-Teacher	f	0	-1	2	2	1	2	1
30-students		-4	-2	-4	0	-4	0	-4
32-Teacher	f	-2	1	2	4	2	1	4
32-students		-4	-2	-4	0	-4	0	-4
34-Teacher	f	-1	0	0	3	0	6	3
34-students		-4	-2	-4	0	-4	0	-4

#15Session7	m/f	build	action	int.	out.	stable	comp.	dutiful
62-Teacher	f	-1	2	2	5	-1	1	0
62-students		-4	-2	-3	0	-3	0	-3
63-Teacher	f	-2	1	3	2	2	0	0
63-students		-4	-2	-3	0	-3	0	-3
64-Teacher	f	-2	1	-1	0	4	4	2
64-students		-4	-2	-3	0	-3	0	-3

Study2 Session8 Attributes (with Personality) Scores

#1Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
shooter	m	2	0	-2	-8	-8	-8	-4

#2Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
car1	m	2	-1	-1	1	3	1	0
car2	m	0	1	0	-1	1	-1	3
car3driver	m	3	0	-1	4	6	-1	2
car3passanger	m	0	0	1	2	2	1	0

#3Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
Principle	f	-3	0	4	0	3	3	-1
Counselor	f	-3	0	2	3	7	-1	3
Administrator	m	1	1	-1	4	2	0	3

#4Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
Administrator	f	0	0	2	0	2	2	0
Staff Member	f	-1	1	4	4	3	4	1

#5Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
Staff Member1	f	0	2	3	-4	3	1	2
Staff Member2	f	-1	-1	-3	0	-2	2	-1
Staff Member3	f	-1	0	-1	1	-1	2	-2
Staff Member4	f	-2	-1	-2	0	-3	-1	-2
Staff Member5	f	-3	0	1	-2	-4	-2	-1
Staff Member6	f	-4	1	-2	-3	-1	-2	0
Staff Member7	f	-3	-1	0	0	0	0	-3
Staff Member8	m	1	1	0	1	-6	-1	1
Staff Member9	f	-2	3	-1	-1	1	-3	0
Staff Member10	f	-1	0	0	-3	-5	-3	-3
Staff Member11	m	2	-1	-1	0	-1	1	0
Staff Member12	f	-1	1	-2	0	2	2	-1
Staff Member13	f	-2	0	0	1	-3	-4	1
Staff Member14	m	2	-1	-4	0	-3	2	-1
Staff Member15	m	2	1	-1	-1	-3	1	-1

#6Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
8-Teacher	f	-1	-1	2	3	2	2	0
8-TA	f	-3	1	2	-1	1	1	-1
8-students		-5	-3	-6	0	-6	0	-6
10-Teacher	f	-1	0	7	2	1	2	0
10-TA	f	-2	1	2	2	-1	-1	-1
10-students		-5	-3	-6	0	-6	0	-6
12-Teacher	f	-2	-2	3	-1	2	3	7
12-TA	f	-2	0	0	-1	1	-1	2
12-students		-5	-3	-6	0	-6	0	-6

#7Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
5-Teacher	f	0	0	2	5	6	2	2
5-students		-5	-3	-5	0	-5	0	-5
7-Teacher	f	-2	-1	3	4	3	3	4
7-students		-5	-3	-5	0	-5	0	-5

#8Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
3-Teacher	f	-3	1	4	1	0	4	3
3-TA	m	0	2	0	-1	0	1	3
3-students		-4	-3	-8	0	-8	0	-8
6-Teacher	f	-2	-1	2	3	1	0	-1
6-TA	f	-4	0	3	2	0	2	2
6-students		-6	-4	-11	0	-11	0	-11

#9Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
1-Teacher	f	-1	1	3	5	5	0	5
1-TA	f	-2	1	3	-1	1	-1	0
1-students		-6	-4	-7	0	-7	0	-7
53-Teacher	m	1	-2	2	0	1	3	3
53-TA	f	-1	1	1	2	-1	1	-1
53-students		-6	-4	-8	0	-8	0	-8
54-Teacher	f	-1	-1	-1	4	1	0	2
54-TA	f	-2	-1	1	2	-1	-1	1
54-students		-6	-4	-7	0	-7	0	-7
56-Teacher	f	-3	1	2	2	4	3	2
56-TA	f	-3	1	1	2	-1	0	-1
56-students		-6	-4	-8	0	-8	0	-8

#10Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
50-Teacher	f	-2	1	1	3	2	3	1
50-TA	f	-2	0	-1	1	-1	3	4
50-students		-5	-3	-6	0	-6	0	-6
52-Teacher	f	-2	1	0	-1	2	4	1
52-TA	f	-2	0	0	0	0	1	0
52-students		-5	-3	-6	0	-6	0	-6

#11Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
48-Teacher	f	-3	1	0	4	-1	4	6
48-students		-4	-2	-4	0	-4	0	-4
49-Teacher	f	-2	0	1	4	1	3	3
49-students		-6	-4	-8	0	-8	0	-8
51-Teacher	f	-3	0	1	6	3	2	6
51-students		-5	-3	-6	0	-6	0	-6

#12Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
19-Teacher	f	-2	1	3	4	1	-1	3
19-students		-5	-3	-5	0	-5	0	-5
21-Teacher	f	-1	1	4	0	0	5	5
21-students		-5	-3	-5	0	-5	0	-5
23-Teacher	m	3	0	3	4	4	4	4
23-students		-5	-3	-5	0	-5	0	-5
25-Teacher	f	-3	0	1	2	2	3	3
25-students		-4	-2	-4	0	-4	0	-4

#13Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
42-Teacher	f	-2	0	4	2	3	0	2
42-students		-4	-2	-3	0	-3	0	-3
46-Teacher	f	-3	1	5	2	3	1	0
46-students		-4	-2	-3	0	-3	0	-3

#14Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
26-Teacher	f	-1	-1	1	2	2	4	0
26-students		-4	-2	-4	0	-4	0	-4
28-Teacher	f	-2	2	2	3	3	1	2
28-students		-4	-2	-4	0	-4	0	-4
30-Teacher	m	2	1	1	1	4	5	4
30-students		-4	-2	-4	0	-4	0	-4
32-Teacher	f	-1	-1	1	5	1	3	2
32-students		-4	-2	-4	0	-4	0	-4
34-Teacher	f	-2	0	-1	4	3	2	-1
34-students		-4	-2	-4	0	-4	0	-4

#15Session8	m/f	build	action	int.	out.	stable	comp.	dutiful
62-Teacher	f	0	1	3	1	0	3	3
62-students		-4	-2	-3	0	-3	0	-3
63-Teacher	f	0	-1	2	7	1	3	0
63-students		-4	-2	-3	0	-3	0	-3
64-Teacher	f	-2	-1	3	5	3	3	-1
64-students		-4	-2	-3	0	-3	0	-3

Study2 Session9 Attributes (with Personality) Scores

#1Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
shooter	m	2	0	-2	-8	-8	-8	-4

#2Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
car1	f	-2	0	1	4	-1	3	0
car2	m	2	1	2	-1	1	3	1
car3driver	m	3	1	1	-1	-1	1	2
car3passanger	m	2	0	3	3	2	-1	0

#3Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
Principle	f	-3	-1	3	3	5	0	2
Counselor	f	-3	0	0	3	3	1	0
Administrator	f	-2	0	1	4	0	-1	-1

#4Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
Administrator	f	-2	0	-1	1	5	6	4
Staff Member	f	-1	-1	3	2	2	3	1

#5Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
Staff Member1	f	-4	0	0	-2	-2	3	-3
Staff Member2	f	-3	-2	-2	-1	-1	-2	-2
Staff Member3	f	-1	-1	-1	3	-7	2	0
Staff Member4	f	-3	-1	-2	-1	-2	-4	-3
Staff Member5	f	-3	0	-1	-2	0	-3	2
Staff Member6	f	-2	0	0	-2	-2	-3	-4
Staff Member7	f	-2	-2	-2	0	5	-3	-2
Staff Member8	f	-2	1	-2	2	-2	-2	1
Staff Member9	f	-2	-1	0	-1	0	2	-3
Staff Member10	m	1	1	-3	-1	-2	1	1
Staff Member11	f	0	0	2	-3	-2	-3	-3
Staff Member12	f	-1	0	1	-3	0	-4	-5
Staff Member13	f	-2	-1	-2	1	4	-1	-2
Staff Member14	f	-2	-1	4	2	1	-4	1
Staff Member15	m	2	0	2	0	-3	-2	0

#6Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
8-Teacher	f	-1	1	-1	0	3	1	-1
8-TA	f	-3	1	0	-1	2	1	2
8-students		-5	-3	-6	0	-6	0	-6
10-Teacher	f	-3	0	5	2	3	3	4
10-TA	f	0	0	1	3	1	-1	2
10-students		-5	-3	-6	0	-6	0	-6
12-Teacher	m	1	-1	-1	1	1	-1	1
12-TA	f	-2	1	1	2	0	4	2
12-students		-5	-3	-6	0	-6	0	-6

#7Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
5-Teacher	f	-2	-1	5	2	-1	2	3
5-students		-5	-3	-5	0	-5	0	-5
7-Teacher	m	0	-1	2	5	-1	0	2
7-students		-5	-3	-5	0	-5	0	-5

#8Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
3-Teacher	f	-3	0	-1	3	3	1	3
3-TA	f	-1	0	1	-1	-1	-1	2
3-students		-4	-3	-8	0	-8	0	-8
6-Teacher	f	-1	3	4	3	1	1	4
6-TA	f	-2	0	1	4	1	2	0
6-students		-6	-4	-11	0	-11	0	-11

#9Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
1-Teacher	f	-2	1	5	3	2	0	0
1-TA	f	-1	1	2	2	-1	-1	2
1-students		-6	-4	-7	0	-7	0	-7
53-Teacher	f	-3	-1	3	3	7	2	-1
53-TA	m	2	-1	1	-1	4	3	0
53-students		-6	-4	-8	0	-8	0	-8
54-Teacher	f	-2	0	1	0	2	3	-1
54-TA	f	-1	1	0	0	2	-1	1
54-students		-6	-4	-7	0	-7	0	-7
56-Teacher	f	-3	2	2	2	2	3	2
56-TA	f	-3	1	2	1	-1	0	1
56-students		-6	-4	-8	0	-8	0	-8

#10Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
50-Teacher	f	-3	0	1	-1	0	0	0
50-TA	f	0	0	-1	2	1	2	-1
50-students		-5	-3	-6	0	-6	0	-6
52-Teacher	f	-1	-2	0	1	0	3	3
52-TA	f	-3	0	3	3	2	-1	-1
52-students		-5	-3	-6	0	-6	0	-6

#11Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
48-Teacher	f	-3	0	1	2	2	4	3
48-students		-4	-2	-3	0	-3	0	-3
49-Teacher	f	-2	-1	3	2	3	7	2
49-students		-5	-3	-6	0	-6	0	-6
51-Teacher	f	-1	0	0	1	-1	4	-1
51-students		-6	-4	-7	0	-7	0	-7

#12Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
19-Teacher	f	-1	0	2	2	5	4	3
19-students		-5	-3	-5	0	-5	0	-5
21-Teacher	f	-3	-1	3	3	0	3	3
21-students		-5	-3	-5	0	-5	0	-5
23-Teacher	f	-4	1	1	1	3	3	2
23-students		-5	-3	-5	0	-5	0	-5
25-Teacher	f	-1	1	1	-1	5	0	4
25-students		-4	-2	-4	0	-4	0	-4

#13Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
42-Teacher	m	2	1	0	1	1	3	1
42-students		-4	-2	-3	0	-3	0	-3
46-Teacher	f	-2	-1	-1	1	1	1	-1
46-students		-4	-2	-3	0	-3	0	-3

#14Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
26-Teacher	m	1	0	4	1	2	-1	0
26-students		-4	-2	-4	0	-4	0	-4
28-Teacher	f	-1	1	3	4	4	2	3
28-students		-4	-2	-4	0	-4	0	-4
30-Teacher	f	0	1	5	4	2	3	3
30-students		-4	-2	-4	0	-4	0	-4
32-Teacher	f	-3	0	3	1	3	1	3
32-students		-4	-2	-4	0	-4	0	-4
34-Teacher	f	-3	0	-1	0	0	2	4
34-students		-4	-2	-4	0	-4	0	-4

#15Session9	m/f	build	action	int.	out.	stable	comp.	dutiful
62-Teacher	f	-2	0	3	2	2	3	3
62-students		-4	-2	-3	0	-3	0	-3
63-Teacher	f	-2	0	1	2	4	5	4
63-students		-4	-2	-3	0	-3	0	-3
64-Teacher	f	-1	-1	5	2	-1	0	2
64-students		-4	-2	-3	0	-3	0	-3

Study2 Session10 Attributes (with Personality) Scores

#1Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
shooter	m	2	0	-2	-8	-8	-8	-4

#2Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
car1	m	2	-1	-1	-1	-1	-1	2
car2	m	2	0	0	0	-1	3	1
car3driver	m	2	0	1	0	5	-1	-1
car3passanger	m	1	0	-1	4	0	0	-1

#3Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
Principle	f	-1	1	3	2	2	3	2
Counselor	f	-3	0	3	2	3	1	3
Administrator	f	-3	0	1	3	3	0	-1

#4Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
Administrator	f	-3	1	3	4	0	2	3
Staff Member	f	-2	2	0	2	0	2	2

#5Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
Staff Member1	m	2	0	1	-1	1	2	1
Staff Member2	f	-2	-2	0	-2	1	1	-4
Staff Member3	f	-2	0	0	1	-1	-4	0
Staff Member4	f	-3	-2	1	0	1	-1	-1
Staff Member5	f	-4	1	-1	-2	1	-4	-4
Staff Member6	f	-2	-2	-1	-1	0	-1	4
Staff Member7	f	-3	2	-1	-2	-3	-1	-1
Staff Member8	f	-3	1	-3	0	-2	-1	-2
Staff Member9	f	-2	-1	-4	-1	-3	-1	-1
Staff Member10	f	-1	-1	1	-1	-3	-3	-1
Staff Member11	m	2	0	-3	-1	-2	2	-3
Staff Member12	m	2	0	-1	1	-3	0	-2
Staff Member13	m	3	1	-1	3	-2	-1	-2
Staff Member14	f	-1	0	-1	-2	-1	1	-3
Staff Member15	f	-1	-1	-2	3	0	0	0

#6Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
8-Teacher	f	-2	-2	-1	2	3	3	3
8-TA	f	-3	-1	2	-1	-1	-1	0
8-students		-5	-3	-6	0	-6	0	-6
10-Teacher	f	-2	1	5	0	4	2	-1
10-TA	f	-2	0	0	0	4	2	0
10-students		-5	-3	-6	0	-6	0	-6
12-Teacher	f	-4	-2	5	4	4	1	5
12-TA	f	-2	1	2	3	-1	1	3
12-students		-5	-3	-6	0	-6	0	-6

#7Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
rm5-Teacher	f	-1	0	2	3	2	3	2
rm5-students		-5	-3	-5	0	-5	0	-5
rm7-Teacher	f	-4	-1	3	2	0	2	1
rm7-students		-5	-3	-5	0	-5	0	-5

#8Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
rm3-Teacher	f	-1	0	1	2	3	2	3
rm3-TA	f	-3	0	2	6	4	-1	-1
rm3-students		-4	-3	-8	0	-8	0	-8
rm6-Teacher	f	-5	1	4	5	2	0	2
rm6-TA	f	-1	0	0	-1	2	3	1
rm6-students		-6	-4	-11	0	-11	0	-11

#9Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
rm1-Teacher	f	-2	0	2	2	0	4	4
rm1-TA	f	-2	2	1	1	1	4	-1
rm1-students		-6	-4	-7	0	-7	0	-7
rm53-Teacher	f	-3	2	-1	0	1	0	0
rm53-TA	m	1	2	2	3	1	2	1
rm53-students		-6	-4	-8	0	-8	0	-8
rm54-Teacher	f	-1	0	-1	2	-1	0	4
rm54-TA	f	-2	0	-1	1	0	0	0
rm54-students		-6	-4	-7	0	-7	0	-7
rm56-Teacher	f	-2	-1	3	1	2	2	2
rm56-TA	m	1	0	2	2	0	2	-1
rm56-students		-6	-4	-8	0	-8	0	-8

#10Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
rm50-Teacher	f	-2	-1	4	0	-1	2	1
rm50-TA	f	-3	1	2	1	2	2	1
rm50-students		-5	-3	-6	0	-6	0	-6
rm52-Teacher	f	-2	-1	4	1	5	3	4
rm52-TA	f	-3	-1	2	0	1	0	1
rm52-students		-5	-3	-6	0	-6	0	-6

#11Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
rm48-Teacher	f	-2	-1	2	4	1	3	1
rm48-students		-5	-3	-6	0	-6	0	-6
rm49-Teacher	f	-1	-1	1	2	4	4	2
rm49-students		-4	-2	-4	0	-4	0	-4
rm51-Teacher	f	-3	-1	3	3	4	2	3
rm51-students		-6	-4	-8	0	-8	0	-8

#12Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
rm19-Teacher	f	-1	0	3	2	1	4	5
rm19-students		-5	-3	-5	0	-5	0	-5
rm21-Teacher	f	-2	-1	2	4	2	0	2
rm21-students		-5	-3	-5	0	-5	0	-5
rm23-Teacher	f	-2	0	0	1	3	-1	0
rm23-students		-5	-3	-5	0	-5	0	-5
rm25-Teacher	f	-2	1	0	3	5	4	3
rm25-students		-4	-2	-4	0	-4	0	-4

#13Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
rm42-Teacher	f	-1	1	4	-1	5	4	0
rm42-students		-4	-2	-3	0	-3	0	-3
rm46-Teacher	f	-1	-1	6	2	1	3	3
rm46-students		-4	-2	-3	0	-3	0	-3

#14Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
rm26-Teacher	f	-3	-2	4	3	-1	3	0
rm26-students		-4	-2	-4	0	-4	0	-4
rm28-Teacher	f	-2	0	3	3	3	5	1
rm28-students		-4	-2	-4	0	-4	0	-4
rm30-Teacher	f	-3	0	4	3	3	-1	4
rm30-students		-4	-2	-4	0	-4	0	-4
rm32-Teacher	f	0	1	5	2	2	1	3
rm32-students		-4	-2	-4	0	-4	0	-4
rm34-Teacher	f	-1	0	0	1	0	0	2
rm34-students		-4	-2	-4	0	-4	0	-4

#15Session10	m/f	build	action	int.	out.	stable	comp.	dutiful
rm62-Teacher	f	-1	-1	2	0	4	-1	4
rm62-students		-4	-2	-3	0	-3	0	-3
rm63-Teacher	f	-2	-1	1	3	4	-1	0
rm63-students		-4	-2	-3	0	-3	0	-3
rm64-Teacher	f	-1	-1	4	1	0	2	0
rm64-students		-4	-2	-3	0	-3	0	-3

This particular tabletop structure can serve as a prototype for creating computational models to simulate active-shooter events. Presented are the variables to define the agents, the magnitude and distribution of these variables, how these variables affect the simulation, the time required to complete several likely tasks in such a scenario and the difficulty of these tasks.

This structure consists of many different aspects that needed to be represented and addressed. This consists of: the event location; all the people involved including the shooter, the adults and children at the school, and the police; how to handle the passage of time, both total time elapsed and time required to complete different tasks; and how to determine results when individuals attempt actions with uncertain outcomes.

All of that was done. This resulted in a structure that can be implemented into computational models for improving these types of simulations, better capturing human behavior.

In computer simulations, representation of terrain features may be addressed by software (Page & Smith 1998). For these tabletop roleplaying simulations of active-shooter events the terrain is the floor plans of the school indicating the locations of wall, rooms, doors, windows, furniture, fire alarms, and fire extinguishers. Representation of doors and windows also needs to indicate which way they open and how they lock and unlock. This is straightforward to translate to a computer model and any such floor plan could be implemented to represent different active-shooter event locations.

CHAPTER 4: RESULTS

Both studies produced informative results proving the validity of using a tabletop roleplaying structure for improving computational models.

As the moderator of these tabletop roleplaying sessions, I observed the players becoming fully engaged in the event. They experienced to some degree the emotions one would expect in a real active-shooter event; they did not want their character to die. This was similar to observations I made of citizens participating in live-action police active-shooter training exercises. These live-action exercises required over a dozen police officers and dozens of citizen participants and involved shutting down parts of a university or college campus. The tabletop roleplaying recreated these experiences with much less time, money, and overhead.

Study1

The roleplaying data was significantly closer to real world data than that from the computational model. The results are listed is in Table 6 and Table 7 below.

For study1, there was an additional line for the protocol of the shooter role. This line was one of the following three: will not be taken alive, save one bullet for self; fight to the end, never stop; or surrender to cops to see results of work. I attempted to see if these cues would affect the way the event ended. They did not. I observed these lines being ignored by the player portraying the shooter character. Once in the midst of the simulation, it seemed adrenalin and emotions were running high. The player portraying the shooter character made quick, in the moment decisions based on the immediate situation. The initial plans or intensions were forgotten. This usually included any strategies the player had at the start of a session. Once the action started happening decisions seemed to be more instinctual.

Table 6: Study1 session results

Session	Duration (seconds)	Number of Casualties	Average Time Between Casualties (seconds)
1	110	16	6.875
2	700	22	31.82
3	380	7	54.29
4	24	30	0.8000 (outlier)
5	27	15	1.800
6	40	3	13.33
7	576	37	15.57
8	546	26	21.00
9	25	2	12.50
10	342	15	22.80
11	41	10	4.100
12	27	5	5.400
13	18	11	1.636
14	334	17	19.65
15	116	13	8.923
16	72	5	14.40
17	129	20	6.450

The categories of data to track were selected because they were the same presented in Anklam, et al. (2015) of the AnyLogic® data. The data in Table 6 is for each of the seventeen sessions in study1. The sessions ended when the shooter was killed or restrained; same as the AnyLogic® simulations. Some were killed quickly by armed resource officers or from others that took the shooter's gun, some took a long time for police to arrive and track down the shooter.

Session 4 is labeled as an outlier. For this session, the duration is low but not the lowest and the casualties are high but not the highest. However, the combination of these two produced an extra low average time between casualties. This session was unique because the shooter player had their character run down the unoccupied back hallway and went straight to the cafeteria and without hesitation began shooting the people in the heavily populated and open area. Then the armed resource officer ran to the cafeteria and immediately shot and killed the shooter. This was the only session that had all of these particular actions happen in such a short time frame. Study1 was a fictional school; these actions might not have been possible in a real school. However, the data is presented both with and without this outlier in Table 7.

The data in Table 7 are averages from the sessions. The real world data was published in Anklam, et al. (2015) and was aggregated from 66 active-shooter events over a five-year period.

Even with the outlier, the data is much closer to the real world data than the AnyLogic® data; in fact, the average duration is slightly closer. However, without this outlier the average number of casualties and averaged from each event’s time between casualties is perfect or near perfect matches of the real world data.

The averaged from each event time between casualties is the results of taking the average of all the average time between casualties for the sessions in Table 6. It is not dividing the average duration in Table 7 by the average number of casualties in Table 7. This would distort the results because each session is a separate event and produces its own separate results. Combining sessions with other sessions would not be an accurate way to view the data. However, even if this is done the results are still significantly closer to the real world data than the data from AnyLogic®.

The focus of this study was on the knowledge gained from the simulation compared to current models, not on the participants. Therefore, the experiences of the participants were not a concern. The goal was to use this structure to inform better AI run simulation design. However, participants did learn about active-shooter events and school layouts; for example how long it takes police to arrive and the fact most school windows do not allow for easy escape.

Table 7: Study1 total results

Data Source	Average Duration (seconds)	Average Number of Casualties	Averaged From Each Event Time Between Casualties (seconds)
AnyLogic®	405.0	9.500	42.63
real world	210.0	14.00	15.00
Tabletop Roleplaying without outlier	217.7	14.00	15.03
Tabletop Roleplaying with outlier	206.3	14.94	14.20

Study2

Simulations with attributes generated data significantly closer to real world data from the actual real world event than simulations without attributes. The results are listed in Table 8 and Table 9 below. The total number of casualties and the number of adult casualties were recorded for each simulation session. From this, the ratio of adult casualties to total casualties was calculated.

Study1 simulated the fictional scenario in Anklam, et al. (2015) and the real world data was an aggregate of 66 events from over a five-year period. The real world data in study2 was from one particular real world active-shooter event. Accurately simulating and producing data to match one particular event is significantly more difficult than simulating a fictional event with limited parameters and producing data that matches an aggregate of several events. However, the information provided by the FBI was a lot more detailed on this event, so more detail could be included in the simulation.

The only reason this particular event was even chosen was the quantity and availability of the information, much of which was disturbing to review. Data that stood out were the casualties. Unfortunately twenty-six people lost their lives that day, twenty of those were children in the first grade.

It is the goal of this work to help police officers prevent or mitigate this type of loss in the future. The intent is to provide police officers and schools with better means of simulating these events so they can increase their training and preparation and respond as effectively as possible. Not only is this tabletop roleplaying structure a tool to assist police it can be informative to school administrators and teachers as well.

The total number of casualties and the number of adult casualties from the each of the tabletop roleplaying sessions are listed in Table 8. The data in Table 9 are the averaged values from these sessions, in the same manner as Table 7 for study1. However, the sessions were separated into two categories, those without attributes and those with attributes. These were quantified values to differentiate characters from one another.

The data from sessions with attributes were significantly closer to the real world data than those without. This shows the benefits to incorporating attributes and provides more quantified variables for computational models. Distinctions between sessions with attributes but not personality attributes and sessions with personality attributes were not significant. It was observations in study1 that the shooter player ignored some details in the protocols in the heat of a tabletop roleplaying session of an active-shooter event. Similarly, the players in study2 sessions with personality attributes, often seemed to replace these character traits with their own personalities.

In tabletop roleplaying games, players often portray characters with personalities much different from their own. The same is true for actors and their roles. Perhaps the reason the players in these tabletop roleplaying sessions did not take on the personality traits of their characters was due to the inexperience the players had with roleplaying characters with personalities different from their own. Perhaps since players controlled multiple characters it was too much to track. Regardless the personality traits did not have significant impact on results positive or negative so were not isolated in Table 9.

Another observed behavior may be another example of a player's personality trumping that of the character. This was the way teachers were portrayed by the players. This was based on the player's, not the teacher character's, gender. Both would fight the shooter if confronted. However, only male players chose to have their teacher characters leave the students to go after the shooter. The gender of the teacher character was not a significant factor. Only some male players did this but no female players ever had their teacher characters leave the students.

Table 8: Study2 session results

Session	Total Casualties	Adult Casualties	Adult Casualty ratio (1 in)
1	20	2	10.00
2	23	3	7.667
3	8	2	4.000
4	20	3	6.667
5	28	5	5.600
6	45	6	7.500
7	5	2	2.500
8	55	9	6.111
9	9	4	2.250
10	17	7	2.429

Table 9: Study2 total results

Data Source	Total Casualties	Adult Casualties	Adult Casualty ratio (1 in)
Average without Attributes	17.75	2.500	7.083
Average with Attributes	26.50	5.500	4.398
Real world	26	6	4.333

CHAPTER 5: CONCLUSIONS

5.1 Summary

Roleplaying is superior to current computational models for simulating events involving human interactions (Green, 2002). Tabletop roleplaying expands the types of events that can benefit from roleplaying by introducing a means to represent physical objects and people and their relative positions and distances from each other.

In order to maximize the potential benefits from roleplaying for serious use as a simulation, scientific principles have to be incorporated. This requires each aspect of tabletop roleplaying to be examined. When aspects are found that conflict with sound scientific principles, they should be changed to reflect current knowledge. A central aspect of roleplaying is the characters. To have these characters simulate real or realistic people then scientifically sound abilities have to be modeled.

For this dissertation, I developed a tabletop roleplaying structure that is superior to current computational models for simulating active-shooter events. This structure is based on scientific research from far-reaching but relevant fields. It is defined mathematically with quantified values and formulaic relationships; this design facilitates its implementation into computational models to improve their performance.

I proved the benefits of this structure by running several tabletop roleplaying sessions using this structure and comparing the results to those from an industry accepted computational model for simulation active-shooter events (Anklam, et al., 2015). The tabletop roleplaying with this structure produced data significantly closer to the real world data than the computational model. The real world data was averaged from sixty-six active-shooter events over a five-year period.

I further proved the validity of using this tabletop roleplaying structure by recreating a particular active-shooter event, not an average from multiple events. The data generated was compared to the real world data of this one event. Then I significantly improved the accuracy of this structure. This was achieved by adding quantified attributes to distinguish individual differences between the characters represented in the simulation. The tabletop roleplaying with attributes produced results significantly closer to the real world data. These attributes are were also defined and scaled based on the reviewed research. Their addition to the tabletop roleplaying structure increased accuracy and are additional quantified variables capable of being incorporated into computational models.

These attributes allowed the tabletop roleplaying structure to further model real world behavior more accurately. Having this behavior modeled with quantified attributes makes it possible to use the simulation to capture this behavior and introduce it to computational models.

This tabletop roleplaying structure for simulating active shooter events can now be used to improve computational models. This is an asset for police departments and organizations, offering benefits to active-shooter training and planning. It allows multiple scenarios to be run in the safety and reduced overhead and expense of a simulated environment. It will allow the police to be better prepared to respond to these tragic events. It will help save lives.

5.2 Future Work

Now that this tabletop roleplaying structure for simulating active-shooter events has been defined and its validity confirmed, the structure could be implemented with a computational model. The effectiveness of this computational model could be tested by simulating real world events and comparing the data generated to the real world data. Continuously comparing data from the computational model to data form the tabletop roleplaying structure could allow iterated improvements.

Police departments and organization could have some groups of police officers use the tabletop roleplaying structure and others that do not. Then evaluations of the the two groups could be made to measure the effectiveness of the structure. If implemented into a computational model, the data from the sessions could be collected effectively and efficiently.

Schools could benefit from this structure as well. Protocols could be tested or taught. School architectural could be tested for safety. Not all buildings are equally safe. After studying active-shooter events, participating in active-shooter training, and running active-shooter simulations, it is clear to me that having additional exits from every location (including each classroom) to the outside can greatly increase the chance for survival. Multiple exits offer more chances to get away. Evacuation or leaving is not always the best option but individuals with only one way out can have that way blocked or threatened and have this option taken from them.

Anklam, et al. (2015) points out from numerous studies that enacting laws enabling individuals to be armed reduces violent crime in those areas. This includes school campuses. Criminals migrate to areas where individuals are not armed, such as “gun-free” zones like schools. This could be simulated with this structure by having multiple locations with different laws and allow the shooter to choose the target.

Because of its novelty and scope, the potential for discovery from using this tabletop roleplaying structure is vast. There will likely be new questions and research topics arise that are difficult to foresee but may emerge from incorporating so many diverse factors in one structure.

The methods used to create the tabletop roleplaying structure for simulating active-shooter events has been fully described. This enables it to be modified for other purposes. This could range from planning, to allowing users to assess situations or characters modeled, to forecasting likely and possible outcomes, to education on matters beyond active-shooter training.

Unproven concepts could be implemented for testing. This could range from testing the effectiveness of an instructional or educational technique to determining the legitimacy of a new cognitive theory to testing new police tactics or action plans.

Card, et al. (2012) shows how action plans can be evaluated. This includes both the possible deviations from the plan when carried out and the deviations the plan may have from its goal. These techniques could be incorporated into the structure to do these types of evaluations.

Martin, Sood, & Riedl (2018) have an opposite approach by proposing methods to get artificial intelligence to play tabletop roleplaying games. Future work could bring the two together bridging the gap in the middle, automating a process that more accurately simulates reality.

This tabletop roleplaying structure could be used for educational purposes. The structure could incorporate concepts to be learned. The structure could then be used by student to learn. The lessons could vary from new tactics to the workings of a cognitive model represented in the rules.

This could include police training with scenarios that highlight new techniques to learn. Experienced experts in those techniques could evaluate the students during or after the tabletop roleplaying session or even use the simulation as the test to see if the necessary skills were learned.

As a training tool, evaluations would in part consist of comparing the educational gains and predictive accuracy to existing methods. This could be particularly useful with military and medical experts that may already be familiar with using simulations for training.

This tabletop roleplaying structure can easily be used for teamwork exercises. Time spent training in the simulation may yield even better results than actual teamwork experience because it can condense particular scenarios into a limited period. However, making the simulation as detailed and close to the real situation is desired to maximize benefits (Shapiro, et al., 2004).

For this dissertation, I have attended and participated in multiple active-shooter training exercise and spoken with multiple police departments and military personnel. Surprisingly none had access to interactive hardware or software that would facilitate group interactions for training or planning purposes. All were using static tables and simple cutouts.

A computational model based on this tabletop roleplaying structure could be adopted for the military if there needs are made explicit. For the military, there is a desire to have any software run on multiple different platforms (Page & Smith, 1998).

This highlights the need to consider how best to implement a computational model based on the tabletop roleplaying structure. This could range from desktops, laptops, smart tables, to other mobile devices. There are guidelines for using smart tables and mobile devices to implement this type of structure based on existing methods used for board games (Eyles & Eglin, 2007). This is referred to as tabletop technology.

Tabletop environments should model character abilities in a concise and coherent way so players can understand and use these abilities as they interact with the simulated world. Players must also be able to manipulate these models easily for a variety of situations to reflect the reaction and choices of the individual to the changing current state of affairs (Ruben, 1999).

For the current tabletop roleplaying structure, this meant limited rules and attributes so the inexperienced player could keep track of it all. However, technology could expand upon the details represented.

Integrated technology could portray aspects of a simulation or provide a more immersive experience within a tabletop roleplaying environment, which results in greater learning and retention (Squire & Jenkins, 2003). Tabletop technology can increase immersion and engagement (Magerkurth, et al., 2004). This would play a factor in decision making of both the active-shooter and those responding to him.

Since tabletop roleplaying has aspects in common with board games such as participants sitting in close proximity around a table and manipulating physical artifacts, technology used in board games could be applied to tabletop roleplaying as well (Tychsen, 2006). This includes map views on a smart table or personalized messages, images, or audio sent to individual players' mobile devices or earphones (Lankoski & Heliö, 2002).

Automated technology can perform computationally intense calculations such as ballistic results as well as capturing and evaluating details of a roleplaying session such as time exposed to line of fire and response times. Such evaluations are useful for training and planning (Shute, 2009). Incorporating tabletop technology would also allow for variations in school layouts to be done quickly and easily.

However, integrated technology does not automatically increase immersion or improve simulations. It would be possible to use virtual or augmented reality to replace physical dice or miniatures. Yet this would only reduce the emersion of manipulating physical objects (Magerkurth, Stenzel, & Prante, 2003).

First-person simulations using virtual or augmented reality exist to prepare police officers for their jobs. This work is not intended to compete with that. This third person top-down perspective provides a broader view of the situation, better suited for strategic planning; managing the entire scenario, tracking everyone's location rather than addressing more tactical skills individual police officers have to learn like proper door entry techniques. In addition, the goal is to use the tabletop roleplaying to inform how to create an automated system in which AI replaces all the people, so virtual or augmented reality would not factor in at that stage.

Further calls for future work could lead to new ways to implement existing attributes like personalities. It could also lead to incorporating additional cognitive abilities and instantiate these works and theories into the consolidated tabletop roleplaying structure. The research on cognitive abilities provides a framework for representing and implementing additional attributes and sub-attributes.

Future work would involve breaking attributes into subcategories in an attempt to gain even greater accuracy. These subcategories would be based on existing hierarchies of cognitive and other abilities. The rules for determining outcome could likewise be adjusted to increase accuracy. These changes should be based on existing research with input from active-shooter experts, such as police and military personnel. Additionally, other techniques could be explored to implement and enforce personality traits.

Different techniques could be used to implement more cognitive abilities and sub-abilities. Delaying, highlighting, or misdirecting information to the player is a way to implement aspects of attention that differ between character and player (Wortelen, Lüdtke, & Baumann, 2013). Measuring error rates and reaction times is a way to evaluate attention. Displays could present a concise yet changing view of current relevant material. Applied to attention this could allow sufficient capturing of vast and varied minutia for modeling purposes (Braga, Wilson, Sharp, Wise, & Leech, 2013).

For example, designing an interface that best captures the impact of distractions on the character's ability to focus or the degree to which multitasking affects outcome. A defined and quantified attention attribute, which may differ from the player's ability in magnitude; based on research would expand the structure and perhaps increase accuracy of simulating the characters portrayed (Li & Zhang, 2013). A quantified attribute for attention may be of particular importance because it along with sensory perception would determine what the character is aware of in the simulated world (Cowan, et al., 2005).

The nature of human attention does not allow for complete simultaneous comprehension of all stimuli so the implementation of an interface displayed on a screen could capture the current stimuli of focus while allowing deeper examination of a particular part of the observable field as needed (Bostan & Ogut, 2009).

By focusing on a minimal number of variables at any given time whether a higher-level general structural for a broad overview or a lower-level more precise view for examining details of a particular cognitive aptitude, the immense subject of all cognitive abilities could be conceptualized (Schmidt, et al., 1988).

All of this encourages more engagement and immersion by the players (Squire & Jenkins, 2003). Researchers could test cognitive theories in the simulation to see if they hold true in the simulated world. Educators and students could use this simulation for instruction or study. It could be a tool for teaching cognitive science principles. It could add value to training for any domain (Schmidt & Hunter, 2004). It could improve understanding of how individuals with cognitive abilities different from your own, interact with the world.

Attention is an executive process of limited capacity to focus on a particular task. The amount of attention required to perform a task is also dependent of the level of skill the individual has with the task. Not all skills use up the same amount of attention. Highly trained skills require less attention to perform. Attention can be seen as the conscious control of executive processes. As such it may be a good candidate for a foundation or connection between many of the cognitive models. Therefore focusing on cognitive models for attention may link immediate memory, long-term memory, and perception.

The attention selection models highlight the differences between early and late selection. Physical information such as pitch and loudness for sound get noticed before directing attention to the source. Additional examples of this early selection may be found in pre-attentive search, the ability to notice certain physical cues such as color, shape, and orientation, before we are even conscious of what we are viewing. By contrast most semantic information is not comprehended until after attention has been directed to the source of such information. Other models of attention make the analogy of a spotlight on a map. The items in the light can be accessed easily by executive processes and items beyond, in the dark are ignored. This model does not address the ability to focus on a single item rather than the area of light. It also does not account for the ability to search a space and not get distracted by irrelevant information.

Managing tabletop roleplaying sessions with the added complexity of additional attributes including attention could be aided with tabletop technology. However, this might not be necessary for sessions with fewer characters and players with more experience at tabletop roleplaying because several existing tabletop roleplaying games have much more complexity than this current tabletop roleplaying structure.

In addition to expanding the innate attributes, acquired skills could be incorporated in future versions of the tabletop roleplaying structure. If this is done effectively then the structure could assist in answering cognitive science questions related to skills.

To implement skills into a tabletop structure requires equations and quantified values. This would lead to searching for solutions to existing questions such as is there a ratio between the performance of experts and novices that apply across domains. This may depend on the domain but a universal objective measure that defines experts would be a missing piece to fill in the picture on expertise.

Other questions may arise when including skills into a tabletop roleplaying structure. Does the daily limit of deliberate practice apply separately if expertise is achieved or maintained in multiple domains? This may be true for drastically different domains such as one being an athletic domain and the other being purely an academic one. Assuming one is not able to spend all waking hours in deliberate practice in any number of domains no matter how similar as long as no one domain exceed four hours. Then what are these limits? How different do the domains have to be, assuming it matters at all and the limit of four hours is not fixed for total deliberate practice regardless if spent on a single or multiple domains?

Beyond just a list of attributes and skills, additional concepts can be implemented based on scientific research to expand the tabletop roleplaying structure. One such implementation is a network of skills that are connected to one another based on how these skills are linked in long-term memory (Bermudez, 2010). Figure 4 gives a much simplified example of how such a network might be represented.

Each node is a different skill. The numerical values on the edges represent the distance of the connection between the two skills it connects. The larger the number the weaker the link between the two skills. This can be seen as an amount to overcome in order to connect the two skills. Using a skill with a link to another skill with a distance of five would be less likely to trigger thoughts about that linked skill and would take longer to do so than a link to a skill with a distance of one.

The two separate networks in Figure 4 correspond to declarative and procedural skills, with the numerical values indicating the distance between the two items. In this example if the individual is currently reflecting upon their biological knowledge it would be much easier call to mind information related to medical technology (distance 2) than computer science information (distance 4). These distances would not be universal and would depend heavily on the context in which they were learned. If ballet was learned for the purposes of improving grace and performance on the football field then these two sets of skills will be more closely related than they would be normally.

A character's attributes would also play a role in determining if connections are made and if so how much time is required to do so. Having a high long-term memory score would make such connections more likely and faster but it would still be relatively easier and faster to make connections between skills with link distances of one compared to link distances of five.

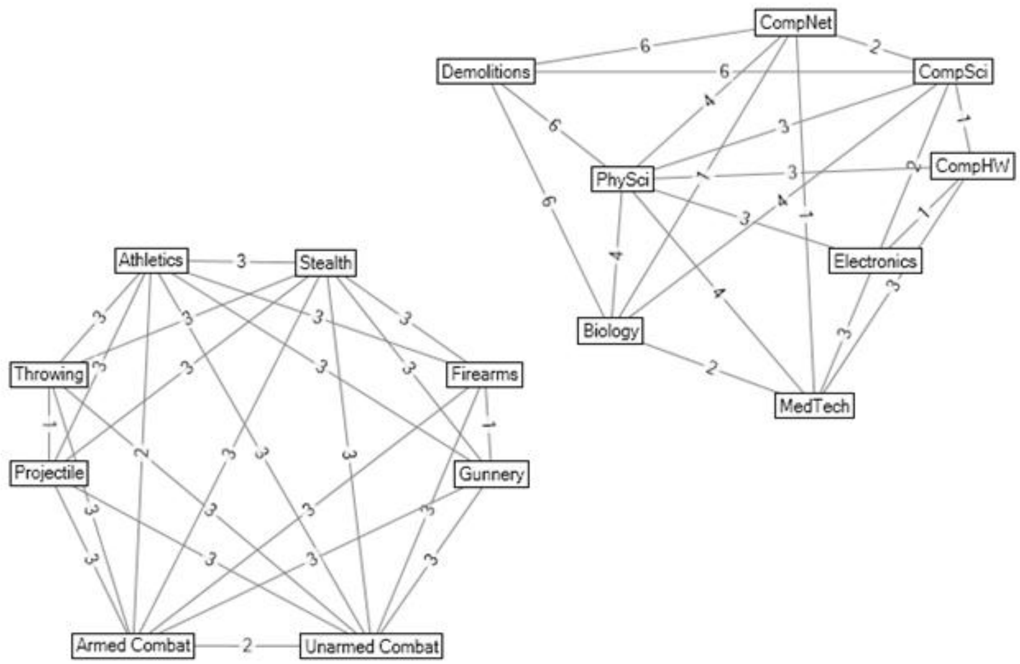


Figure 4. Skill network.

Another means to expand the tabletop roleplaying simulation is implementing the concept of attention (Cowan, et al., 2005). Rather than just a quantified value like the other attributes it could be represented as a bar in Figure 5 of a limited capacity that the player uses to keep track of what their character currently has their attention on. A more involved model could break this bar down further into sub-bars for working-memory and the various sensory attributes (visual, auditory, tactile, and olfactory). These capacities would be based on the related attribute. The items in the bar represent what the character is currently focusing on.

Since there are far more possible things to choose to focus on than there is capacity, choices have to be made and attention has to be divided. Additionally, filling multiple slots with the same area of focus indicates that more attention is being placed on that area. This makes it easier for the character to notice that area in more detail and with quicker response. As Figure 5 shows, skills that are newly learned take up more attention to use than skills that have been mastered. Outside factors like lack of sleep or distracting sounds can have impacts by occupying some of the character's attention capacity.

Time required to swap out one skill for another would be based on the distance of the links between them. The larger the distance the longer it will take to swap the skills. If no direct links exists then the character would require extra time to make the swap. New weak (distant) connections could be made and existing connections could be strengthen (reduce the distance) both with deliberate practice.

Figure 6 shows that an exchange of skills has been made to replace those in Figure 5. Two of the skills, Trained Skill 1a and Trained Skill 1b, are overlapping in the Attention Bar. These skills were labeled 1a and 1b to indicate skills used together in different hands. A collaborative quality exists when such skills are used in a complementary manner. Rather than each taking up their individual allotment of attention they are allowed to overlap. Using one skill sets up the use of the other skill (Guiard, 1987).

As an illustration consider two combative skills, one for blocking the other for attacking with a swinging motion. If a block is performed with the left hand, the left shoulder moves forward and the right shoulder goes back. This backward motion of the right shoulder puts it into position to strike after the block. This is analogous to what takes place in the mind when such skills are performed (Guiard, 1993). In fact the gross motion of the left hand blocking gives a reference point for the right hand to perform the more precise act of swinging to hit the opponent.

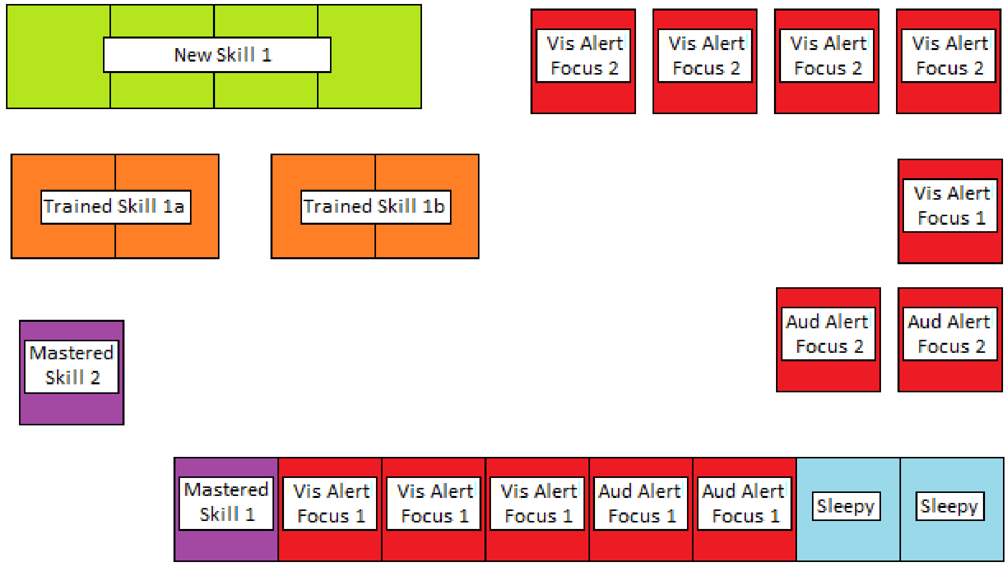


Figure 5. Attention 1.

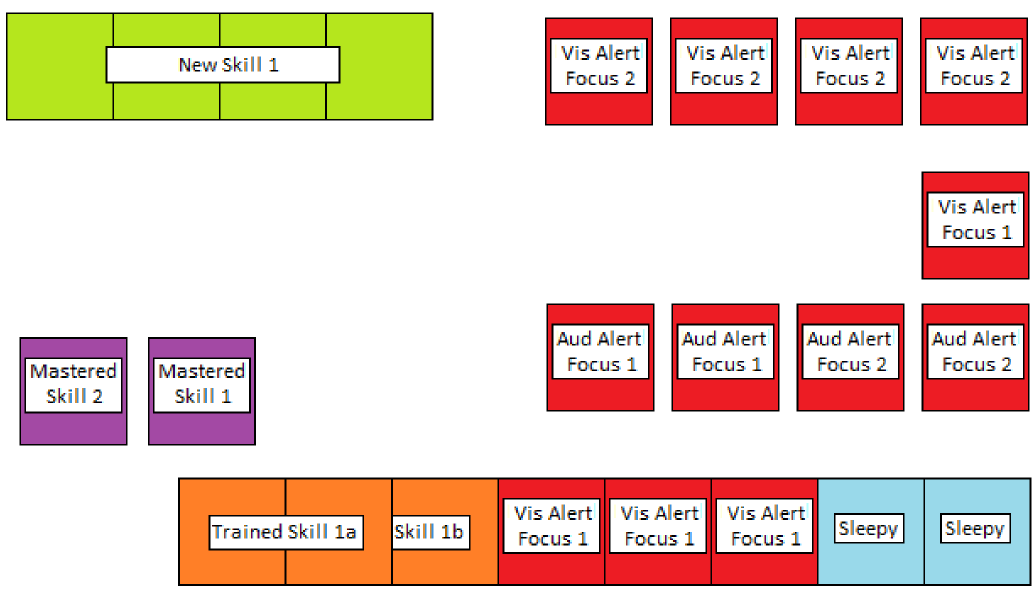


Figure 6. Attention 2.

This and other future work would not have been appropriate for study1 or study2 due to the scale of individuals involved. Additionally this future work may involve a learning curve for the players. However, now that I have validated the superiority of tabletop roleplaying over current computational models to simulate active-shooter events and demonstrated how the tabletop roleplaying can have its performance improved and quantified so it can be implemented into computational models, the variety of tasks tabletop roleplaying can simulate can continue to be expanded.

Now that the door has been opened, it is my intent to continue to explore the benefits tabletop roleplaying can provide for designing computational models to simulate human behavior. Narrowly this will include recreating more historical active-shooter events so the results can be compared to real world data of more particular events. However, more broadly, I will compare roleplaying simulations to various and farther-reaching computational models to explore and address their limitations and search for ways they can be improved with tabletop roleplaying.

Some of these areas of expansion will warrant further details as mentioned in this future work. This will include more precise units of time; dealing with fractions of seconds. It also consists of more numerical precision with the attributes, skills, target numbers, modifiers and dice, as discussed in the Explanation section above. This along with more detailed sub-attributes, skills, physics, hit-locations for attacks, medical/wound data for injuries, and weapon values will be required for the structure to be a fully fleshed out tabletop roleplaying simulation, going deeper to incorporate all the aspects in the reviewed and expanding relevant areas of research. I have implemented such a tabletop roleplaying simulation in a game format, which is an extension of the structure presented here. However, this expanded version stills need to be tested with proper situations to simulate and then rigorously scrutinized by experts. Perhaps this deeper structure could be tested with tracking individual police or military units as they progress through training and complete operations.

Once verified, it will be shared with police and military for their use and feedback for further refinement and expansion. It will also be shared with the public in hopes of being used for multiple purposes, including other scientific and serious research uses but also for entertainment, keeping my promise to play-testers.

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APPENDIX A: DETAILED STUDY DATA

Study2: Character Representations for Map

3T	6T
3A	6A
3b	6b
3c	6c
3d	6d
3e	6e
3f	6f
3g	6g
3h	6h
3i	6i
3j	6j
3k	6k
3l	6l
3m	6m
3n	6n
3o	6o
3p	6p
3q	6q
3r	6r

Cutouts Special Education

53T	56T
53A	56A
53b	56b
53c	56c
53d	56d
53e	56e
53f	56f
53g	56g
53h	56h
53i	56i
53j	56j
53k	56k
53l	56l
53m	56m
53n	56n
53o	56o
53p	56p
53q	56q
53r	56r

Cutouts Preschool

1T	54T
1A	54A
1b	54b
1c	54c
1d	54d
1e	54e
1f	54f
1g	54g
1h	54h
1i	54i
1j	54j
1k	54k
1l	54l
1m	54m
1n	54n
1o	54o
1p	54p
1q	54q
1r	54r

Cutouts Kindergarten

8T	10T	12T	50T	52T
8A	10A	12A	50A	52A
8b	10b	12b	50b	52b
8c	10c	12c	50c	52c
8d	10d	12d	50d	52d
8e	10e	12e	50e	52e
8f	10f	12f	50f	52f
8g	10g	12g	50g	52g
8h	10h	12h	50h	52h
8i	10i	12i	50i	52i
8j	10j	12j	50j	52j
8k	10k	12k	50k	52k
8l	10l	12l	50l	52l
8m	10m	12m	50m	52m
8n	10n	12n	50n	52n
8o	10o	12o	50o	52o
8p	10p	12p	50p	52p
8q	10q	12q	50q	52q
8r	10r	12r	50r	52r

Cutouts First Grade

5T	7T	19T	21T	23T
5A	7A	19A	21A	23A
5b	7b	19b	21b	23b
5c	7c	19c	21c	23c
5d	7d	19d	21d	23d
5e	7e	19e	21e	23e
5f	7f	19f	21f	23f
5g	7g	19g	21g	23g
5h	7h	19h	21h	23h
5i	7i	19i	21i	23i
5j	7j	19j	21j	23j
5k	7k	19k	21k	23k
5l	7l	19l	21l	23l
5m	7m	19m	21m	23m
5n	7n	19n	21n	23n
5o	7o	19o	21o	23o
5p	7p	19p	21p	23p
5q	7q	19q	21q	23q
5r	7r	19r	21r	23r

Cutouts Second Grade

25T	26T	28T	30T	32T	34T
25a	26a	28a	30a	32a	34a
25b	26b	28b	30b	32b	34b
25c	26c	28c	30c	32c	34c
25d	26d	28d	30d	32d	34d
25e	26e	28e	30e	32e	34e
25f	26f	28f	30f	32f	34f
25g	26g	28g	30g	32g	34g
25h	26h	28h	30h	32h	34h
25i	26i	28i	30i	32i	34i
25j	26j	28j	30j	32j	34j
25k	26k	28k	30k	32k	34k
25l	26l	28l	30l	32l	34l
25m	26m	28m	30m	32m	34m
25n	26n	28n	30n	32n	34n
25o	26o	28o	30o	32o	34o
25p	26p	28p	30p	32p	34p
25q	26q	28q	30q	32q	34q
25r	26r	28r	30r	32r	34r

Cutouts Third Grade

42T	46T	62T	63T	64T
42a	46a	62a	63a	64a
42b	46b	62b	63b	64b
42c	46c	62c	63c	64c
42d	46d	62d	63d	64d
42e	46e	62e	63e	64e
42f	46f	62f	63f	64f
42g	46g	62g	63g	64g
42h	46h	62h	63h	64h
42i	46i	62i	63i	64i
42j	46j	62j	63j	64j
42k	46k	62k	63k	64k
42l	46l	62l	63l	64l
42m	46m	62m	63m	64m
42n	46n	62n	63n	64n
42o	46o	62o	63o	64o
42p	46p	62p	63p	64p
42q	46q	62q	63q	64q
42r	46r	62r	63r	64r

Cutouts Fourth Grade

9P	48T	49T	51T
9C	48a	49a	51a
9A	48b	49b	51b
M.A	48c	49c	51c
M.S	48d	49d	51d
S1	48e	49e	51e
S2	48f	49f	51f
S3	48g	49g	51g
S4	48h	49h	51h
S5	48i	49i	51i
S6	48j	49j	51j
S7	48k	49k	51k
S8	48l	49l	51l
S9	48m	49m	51m
S10	48n	49n	51n
S11	48o	49o	51o
S12	48p	49p	51p
S13	48q	49q	51q
S14	48r	49r	51r

Cutouts Other Faculty and Staff and Spanish, Art, and Computer Lab