LATENT CLASS ANALYSIS OF SERIAL MURDERERS

by

Emily Luc

A thesis submitted to the faculty of
The University of North Carolina at Charlotte
in partial fulfillment of the requirements
for the degree of Master of Science in
Criminal Justice

Charlotte

2016

Approved by:

_____
Dr. Matthew Phillips

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Dr. Anita Blowers

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Dr. Shannon Reid

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ABSTRACT

EMILY LUC. Latent class analysis of serial murderers. (Under the direction of DR. MATTHEW PHILLIPS)

Scholars and law enforcement agencies have been analyzing criminals' behavioral and psychological characteristics for decades in order to create profiles, which can be used by authorities to guide serial murder investigations and help apprehend suspects. Within criminology, multiple subgroups of serial murderers have been created to try to understand their motives and to help identify future perpetrators. Although behavioral profiling has traditionally consisted of qualitative techniques, it is the goal of this study to demonstrate the value of quantitative analysis in the profiling process. The primary research question that this project aims to answer empirically is whether there are certain crime scene and personal background characteristics common to serial murders that can be used to uncover latent or underlying classes of serial murderers. To answer this question, this project will rely on serial murder data obtained through a database provided by Radford University/Florida Gulf Coast University, assembled through examination of public documents. The data set includes roughly 175 variables on serial murderers (n= 1,131) who have killed in the United States with three or more victims. To determine if there are underlying clusters of serial murderers, this project will conduct a latent class analysis. If latent classes exist, not only will behavioral profilers be able to use this information, but so too will police departments working on a serial murderer case. Identification of latent classes will allow for individuals without significant experience in profiling to look at the different classes and determine the likelihood that a serial murderer fits into that class, and further know what other variables are commonly

observed within this cluster, thus helping them apprehend the perpetrator. This quantitative approach to profiling through data-driven predictive modeling will add to the larger understanding of criminal behavior patterns that can be expanded to other forms of criminal offending.

INTRODUCTION

Serial murderers are a unique subset of criminals who provide many challenges to law enforcement agencies. Serial murderers are able to evade law enforcement while continuing to commit homicide this combined with the inherent difficulty in understanding their actions fascinates the public and professionals. Serial murderers tend to have many victims, which makes them a popular subject to research (Holmes & DeBurger, 1998). Another unique aspect of serial murderers is the lack of consensus on the definition of a serial murderer (Adjorlolo & Chan, 2014; Allely et al., 2014). The lack of a universal definition also causes many issues when trying to determine the prevalence rates of serial murderers, such as trying to determine if an offender should be categorized as a serial murderer or mass murderer which could lead to the over-reporting or under-reporting of serial murderers.

One of the tools law enforcement agencies have used to combat serial murderers is criminal profiling. Many researchers and professionals have created typologies of serial murderers through the use of criminal profiling. These typologies are often created based on the profilers' experience, training, intuition, and knowledge (Snook et al., 2007). Criminal profiling was widely used to create these typologies because it was very popular at the time and it was believed that using expert's past experience would create accurate typologies. However, researchers have started to question the validity of these typologies that are used in the investigations because of some well publicized criminal profiling failures. These typologies are rarely empirically tested, but the few studies that have tested their empirical validity have found little success for their utility (Canter et al., 2004; Taylor, Lambeth, Green, Bone, & Cahillane, 2012).

This study will examine a data set of serial murderers obtained from the Radford University/Florida Gulf Coast University database to try to determine if there are certain background characteristics that are indicative of crime scene characteristics (Radford/ FGCU Serial Killer Database Research Project, 2015). This study will conduct a latent class analysis (LCA), which uses observed characteristics to determine if there are any underlying subgroups of individuals, known as latent classes. A LCA will be estimated in order to determine if there are clusters of underlying variables that provide the necessary information to create a typology. This study aims to rigorously test criminal profiling research by performing a LCA using concepts from existing typologies to determine if these concepts are empirically valid. In doing so this study provides an empirical approach to profiling serial murderers that law enforcement will be able to use in their investigations. It will also provide a viable methodology for profiling other types of crimes.

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LITERATURE REVIEW

Serial Murderers

Serial murderers have been active for a very long time, going as far back as 331 B.C. in ancient Rome (Newton, 2000). Their presence has been felt in every society and is not limited to one culture. The long history of these offenders, coupled with the amount of victims left in their wake, has made them a popular topic of research. However, it was not until the 1980's that much attention was given to determining effective strategies for investigating serial murderers. (Holmes & DeBurger, 1998; Snook, Eastwood, Gendreau, Goggin, & Cullen, 2007). Many researchers have tried to identify typologies for these criminals to better help identify elements present in the offenders' behavior that are also associated with background characteristics, with the hope that these typologies can aid law enforcement in apprehending them (Dietz, 1986; Hazelwood & Douglas, 1980; Holmes & DeBurger, 1998; Miller, 2014; Rappaport, 1988; Sewall, Krupp, & Lalumiere, 2013).

There is a great deal of variation in the individual characteristics of serial murderers. For example, Jack the Ripper, arguably the most famous serial murderer, had a hunting ground in Victorian England during the late 1800s. He lived a double life, taunted the police, specialized in killing prostitutes, and sexually mutilated his victims (Begg, Fido, & Skinner, 1991; Miller, 2014). Albert Fish was known for being a pedophile, cannibal, sadist, masochist, and serial murderer (Schechter, 1990). Yet another is the Boston Strangler, Albert Desalvo, who killed 13 women in the 1960s. Albert

Desalvo used his charm to gain access to his victims, and exhibited a classic example of escalation in violence, starting off as a voyeur eventually escalating to the point of a serial murderer (Miller, 2014; Rae, 1967). These examples show that not all serial murderers are alike, but can have multiple elements common to this subset of murderers. However, there are unique commonalities among different groups of murderers that theoretically allow for the distinction of groups within typologies.

The term "serial murder" has been defined in many different ways by researchers and law enforcement officers. The majority of definitions require at least three victims, but not all of them do. For example, the current FBI definition only requires two victims. These type of killers are most commonly referred to as serial murderers, serial killers, or serial homicide perpetrator (Miller, 2014). According to Holmes and Holmes (2010), there was a relatively agreed-upon definition in the past for serial killers, which was "the killing of three or more people over a period of more than 30 days, with a significant cooling-off period between the murders" (p. 1). However, there has been a shift in the definitions, moving away from elements such as the location, motive, and offender-victim relationship because they are difficult to operationalize. The new definitions just focus on the number of victims and time scale, making it more difficult to discern a serial murderer from a mass murderer (Adjorlolo & Chan, 2014). One definition of a mass murderer is a person who kills three or more people over a short amount of time, hours or days (Allely, Minnis, Thompson, Wilson, & Gillberg, 2014). An individual could easily fit the definition of a mass murderer and a serial murderer when the definitions are this vague, making it very difficult to classify an offender in order to conduct research.

The FBI defines a serial murder as “the unlawful killing of two or more victims by the same offenders in separate events” (FBI, 2008, p. 12). This definition leads to an over-inclusion of individuals into the category because there are no restrictions on time or intention. A career criminal who was involved in an altercation resulting in the death of someone could easily be classified as a serial murderer because a similar incident could happen in prison. Another example based on the intention element would be a terrorist. The FBI created this definition as a guideline for cases during which they have jurisdiction, it was not conceived with the intentions of being used in research. When offenders are misclassified because of these vague definitions then the research conducted may not be reliable.

The lack of a universal definition is problematic because of the intersection between research and law enforcement. An example of this intersection is that law enforcement will sometimes change their practices based off of research. This is why it is extremely important that there is a universal definition that researchers and law enforcement officials use, because without that, it is difficult to compare various research findings. Researchers also need to be able to use data from police documents when conducting research. If the police are using a different definition for a serial murderer they might not include information in their reports that researchers would need to determine if the offender is a serial murderer based on their own definition (Adjorlolo & Chan, 2014). For example, two previously discussed definitions for serial killers one created by the FBI (2008) is based on the number of victims, and another by Holmes and Holmes (2010) places emphasis on a cooling-off period. Even these prominently used

definitions are inconsistent in their fundamental aspects and this can affect which perpetrators would or would not be counted in research studies.

Since there is not a universal definition it is extremely difficult to determine the prevalence of serial murderers and the number of victims. There is also some difficulty in determining whether an offender meets the definition of serial murder due to the way many researchers set up databases and how law enforcement keep track of records. Depending on the setup of the database, and whether it includes the time between murders and other aspects of the cases, it might not be possible to determine whether someone is a mass murderer, serial murderer, or a career criminal who has committed multiple homicides in their lifetime. Even if the statistics were reliable on the amount of serial murderers caught, there have been many times when law enforcement has suspected a serial murderer, but were not able to apprehend a perpetrator (Adjorlolo & Chan, 2014; Allely et al., 2014). In other words, the case clearance rate is low for serial murderers (Miller, 2014). It is also difficult to determine the prevalence of victims because when serial murderers are caught they are known to overestimate and sometimes lie about the number of victims they have (Allely et al., 2014).

The FBI has estimated the amount of serial killers that have been active in the United States to be between 200 and 500 and are responsible for 2,000 to 3,500 murders a year, which accounts for more than 10% of murders in the United States (Bureau of Justice Statistics, 2003). Others estimate the prevalence of serial murderers as high as 1,500 for all countries (Newton, 2000; Mitchell & Aamodt, 2005). The previously listed obstacles make it extremely difficult to determine the prevalence rates of serial murderers

and explain why there is such a huge variance in the numbers that are out there (Adjorlolo & Chan, 2014).

Serial murderers have received much attention over the years from researchers and the media. There is an inherent difficulty in understanding serial murderers that attracts many people to this area of study and what has been written about them (Adjorlolo & Chan, 2014). One thing that makes serial murderers unique is the controversy and lack of consensus on the definition as discussed previously. The lack of consensus on the definition makes it very difficult to determine the prevalence rates. However, compared to other crimes such as robbery, it is known that serial murderers are rare. When there is a serial murderer who cannot be caught there is a deep-seated societal impact, which includes the fear it instills in people (Adjorlolo & Chan, 2014; Allely et al., 2014). Serial murderers tend to be skilled at avoiding police detection or they would not be able to continue killing because law enforcement would stop them. Whatever characteristics enable these perpetrators to continue their killing sprees also makes it difficult for police to detect them. This is why law enforcement use additional tactics to help apprehend these perpetrators. One of these tactics that has been used to capture these types of offenders is criminal profiling.

Types of Profiling

There are a few different types of profiling: geographical profiling, criminal profiling, and crime scene linkage analysis. Geographical profiling takes into account the different crime locations in a series of crimes to determine the origin location of the offender. There are a growing number of programs that enable geographical profiling

being applied to many different crimes (Santtila, Zappalà, Laukkanen, & Picozzi, 2003). For multiple crimes including burglary, robbery, stranger rape, and sometimes, serial murder, researchers have found that offenders travel short distances from their residence to commit the crime (Van der Kemp & Van Koppen, 2008). However, for geographical profiling to be successful a larger number of crime sites is needed; one or two is not enough, as multiple crime sites increase the accuracy of the prediction increases (Van der Kemp & Van Koppen, 2008).

The concept of profiling can be traced back to the Catholic Church trying to identify witches in the late 1400s. The introduction of phrenology in the late 1700s would also be considered a form of profiling because Franz Gall would infer someone's mental capacity based on the structure of their skull. Yet another example of profiling that is not used anymore was conducted by Césare Lombroso, who created a typology for criminals and used 18 physical characteristics to classify individuals as being lower on the evolutionary scale as a way to explain their criminal behavior. In modern times criminal profiling has had its ups and downs. In 1956, a psychiatrist correctly identified characteristics of the New York "Mad Bomber" based on the crime scenes and letters that were sent to the police. Shortly thereafter, in 1972, the Behavioral Science Unit (BSU) which was dedicated to criminal profiling was created at the FBI due to an apparent increase in the number of serial homicide cases. Criminal profiling has fallen out of favor and been criticized due to well publicized failures, for example the Boston Strangler case. The psychiatrist that was consulted in the investigation said that the crimes were committed by two homosexual males, which was a completely inaccurate description of

Albert DeSalvo, the actual perpetrator (Woodworth & Porter, 1999). Another well-known example of a criminal profiling failure is the Washington, D.C. sniper case, where the profilers on the case believed the perpetrator to be a lone White male in his 20s driving a white van. In reality the perpetrators were two Black men aged 41 and 17 driving a blue sedan, these men were actually able to use this wrong profile that had been given to the media to avoid detection (Aamodt, 2008).

Criminal profiling, also known as offender profiling, is "the practice of inferring personality, behavioral, and demographic characteristics of criminals based on crime scene evidence" (Snook et al., 2007, p. 437). Previously there was also a distinction between psychological profiling and criminal profiling. Psychological profiling involved reviewing a person's actions in order to determine something about what type of person they are. This method was typically conducted by psychiatrists, looking at factors such as age, gender, type of weapon, and past abuse. Criminal profiling tends to be conducted by law enforcement officers and their intention is to describe a suspect's behavioral pattern. However, criminal profiling is most useful when psychopathology is involved and looks at personality and behavioral characteristics, which are psychiatric concepts (Douglas, Ressler, Burgess, & Hartman, 1986). These behavioral characteristics are also believed to be reflected in the non-criminal aspects of the perpetrators life and that these characteristics are linked to demographic features (Alison et al., 2002). Douglas et al. (1986) compares the criminal profiling process to making a treatment and diagnoses plan. In current research the distinction between psychological and criminal profiling is not as

prominent as it used to be, and sometimes is referred to as criminal psychological profiling (Kocsis, 2003).

There is concern in the way offender profiling uses crime scene actions to determine background characteristics and personality types. Most often profilers do not specify which principles they rely on (psychological, correlational, or behavioral principles), which is an issue when trying to determine how the profiler made the jump from the crime scene characteristics to the perpetrator's characteristics. However, it is obvious that the process of offender profiling does rely on psychological principles because of the personality traits and characteristics used to describe perpetrators. Nevertheless, the people who conduct profiles often do not have an academic understanding of these psychological principles and use intuition and experience to create these profiles. Due to their lack of knowledge of psychological principles there is a concern that the inferences these profilers make are not appropriate for the psychological definitions of these traits and therefore should not be an inclusion of demographic characteristics based on these traits (Alison, Bennell, Mokros, & Ormerod, 2002).

A main issue is that these profiles are based off traditional trait theories of personality that are no longer used in psychological research because they lacked empirical support. These trait theories do not take in situational factors, and these theories believed that there are consistencies in individual's social behavior across a wide range of situations because of stable and generalized dispositions that sustain over long periods of time. Another issue with using traits in the profiling process is that since traits cannot be observed profilers use the crime scene actions to determine the personality traits of the

perpetrator. These personality traits are then used to describe the crimes scene actions creating a tautological argument (Alison et al., 2002).

There are two major assumptions of offender profiling, consistency and homology. The way consistency is viewed differs depending on the discipline studying it. When criminologists study consistency they look at whether perpetrators are committing the same type of offenses every time they commit a crime, also known as specialization. There is also a psychological approach to consistency and that is what is used in profiling (Alison et al., 2002). The assumption of consistency, also known as the offender consistency hypothesis, is that every time an offense is committed by the same offender they will repeat the offense in a similar pattern (Beauregard & Field, 2008). The behavioral consistencies discussed in psychological research have been shown to have some support (Alison et al., 2002).

Another assumption of offender profiling is the assumption of homology, which is the phenomenon that specific background characteristics are associated with the way crimes are committed. Multiple studies have been conducted on the homology of offenders and the findings demonstrate, with mixed results. The author of one study suggests that maybe researchers are not identifying the right behaviors that are needed to create a successful profile (Beauregard & Field, 2008). Beauregard and Field (2008) found support for offender homology when looking at sexual murderers from the characteristics of prior conflicts with the victims and the age of the offender. However, there are many other research studies that have not been able to find support for the homology assumption in criminal profiling. Kocsis and Palermo (2015) argue that the

reason there is little support is due to a rigid interpretation of the concepts that leads to a trait-based approach. If the homology assumption was incorrect then there would not be as many studies affirming the accuracy of profiling. This disconnect in the results of accuracy of profiling and lack of support for homology is why Kocsis and Palermo (2015) suggest there can be different approaches other than trait-based.

The last type of profiling is case linkage analysis. While offender profiling focuses on specific characteristics the perpetrator might posses, case linkage analysis focuses on whether two separate crimes were committed by the same offender, by examining the different crime scenes (Woodhams & Toye, 2007). Case linkage analysis is also referred to as comparative case analysis, crime scene linkage analysis, or linkage analysis and is normally used for investigating crimes such as murder and stranger rape, but can also be useful for other crimes such as robbery and burglary. Case linkage is often used when the victim does not know the offender and there is no physical evidence for multiple crime scenes that are suspected by police to be committed by the same offender. Due to the common features of case linkage analysis and offender profiling, some researchers in their studies do not differentiate between these two approaches (Woodhams, Bull, & Hollin, 2007). One assumption of case linkage is the offender consistency hypothesis mentioned previously with criminal profiling. However, the key distinction between case linkage analysis and criminal profiling is that case linkage analysis does not assume homology. The process used for this type of profiling is generally based on intuition and experience. Case linkage involves a multistage process that entails: requesting and reading documentation, constructing list of behaviors for

index offence, searching for similar cases, constructing lists of behaviors for other potentially similar offences, identifying similar and dissimilar behaviors, weighing similarities and differences, and writing a report for police and prosecutors. Police organizations have started to automate this process and decrease error through the use of technology and analytic technologies to databases (Woodhams, Bull, & Hollin, 2007).

Criminal Profiling of Violent Crimes

There has been an ongoing argument as to whether criminal profiling, a commonplace technique used as a police investigation tool should be considered more "art" or "science" and whether it is reliable or valid. There are two competing approaches to criminal profiling; clinical and statistical. Clinical techniques are based off of the profilers' experience, intuition, knowledge, and training. Statistical approaches, on the other hand, use "descriptive and inferential statistical models derived from an analysis of characteristics of offenders who have previously committed similar types of crimes" (Snook et al., 2007, p. 438). The wide use of the clinical approach is the reason why some people argue criminal profiling should be considered an "art", unless a statistical approach is used, which then it should be considered a "science".

Criminal profiling is used to aid serial crime investigations, including but not limited to murder, sexual assault, arson, robbery, and burglary (Woodworth & Porter, 1999). Even with a lack of research supporting the utility and validity of the profiles created, there has been an increase in their use among law enforcement agencies (Kocsis, Cooksey, & Irwin, 2002). While there are multiple profiles out there for each of these types of crimes, only a handful of research studies have applied a statistical approach to

criminal profiling (Canter, Alison, Alison, & Wentink, 2004; Fox & Farrington, 2012; Kocsis, Cooksey, & Irwin, 2002; Phillips, M.D., 2016). Among these empirical studies there is still an argument about their utility. Fox & Farrington (2014) were the only study to conduct an experimental evaluation in order to determine the utility of their profile. Since there has only been one study that has tried to determine the utility of their profile law enforcement may be wasting time and energy following inaccurate leads based on untested profiles.

Clinical Typologies of Serial Murderers

Researchers have been creating typologies using a clinical approach to help better understand serial murderers and to help facilitate criminal profiling. One commonly known typology is the Holmes typology which consists of five different categories (Holmes & DeBurger, 1985). The first category of the typology is the *visionary serial killer* who suffers from delusions or hallucinations that instruct them to kill and the victims tend to be strangers. The *mission serial killer* follows political or religious imperatives to eliminate a specific group. The *comfort-oriented serial killer* has a utilitarian purpose to their motive. An example of this would be a hired assassin who works for profit. *Hedonistic serial killers* kill because of the sexual pleasure they get from the act. These offenders tend to torture, dismember, and/or mutilate the victim. The last category is the *power/control serial killer* who is similar to the hedonistic serial killer, but these offenders derive pleasure from the control and domination of torturing and killing, rather than the sexual component. One area not included in the typology that Holmes finds very important to assess is the spatial mobility of the killer. There are

geographically stable serial killers that kill in the same area in which they live, while others are transient killers that travel throughout the duration of their killing career (Holmes & DeBurger, 1985; Holmes & DeBurger, 1998; Miller, 2014).

The FBI's Behavioral Science Unit (BSU) created an organized - disorganized dichotomy for serial murderers that is probably the best known, but also controversial, typology (Hazelwood & Douglas, 1980; Miller, 2014). "Organized' serial killers tend to be above average intelligence, and are meticulous and carefully plan their crimes. They believe themselves to be superior to everyone, they typically travel long distances to commit their crimes, they collect trophies or souvenirs, are sophisticated, taunt law enforcement officers, and select victims who are strangers. "Disorganized" serial killers tend to be average or below average intelligence, have a poor self-image, are impulsive and spontaneous, are loners or recluse, and are characterized by overkill[1]. There are also many individuals who meet elements for both organized and disorganized who fall into a mixed category (reviewed by Miller, 2014). Many authorities believe the FBI's dichotomy should be viewed as a continuum rather than a dichotomy (Miller, 2014).

Miller (2014) synthesizes the many different typologies that have been developed, noticing their numerous commonalities and identifies the following subtypes: sexual sadists are those who kill for the pleasure they receive from dominating, humiliating, torturing, controlling, and killing others; delusional killers are on a mission, psychotic, or ideologically driven to eliminate a particular group; custodial killers murder helpless or

[1] Overkill is when the perpetrator uses more force than is necessary to commit the act, characterized by multiple blows and stabs (Miller, 2014).

dependent individuals who are under their care; utilitarian killers are motivated in part by financial or material gain and in part by anger or revenge (Miller, 2014).

Criticisms of Profiling

The Holmes typology and the BSU's dichotomy are considered a clinical approach to criminal profiling. When the FBI profilers were at their peak, they were estimated to be consulting on 1,000 cases per year (Witkin, 1996). Snook et al. (2007) conducted a meta-analysis on criminal profiling, and out of the 130 criminal profiling articles they found that anecdotal arguments were the most used source of knowledge (60%) and scientific evidence was the second to least used source of knowledge (42%). While the prevalence of each of these sources shows that the clinical approach is very prominently used, there is still question of whether or not there is empirical data to support these typologies. Taylor, Lambeth, Green, Bone, & Cahillane (2012) found no empirical support for the FBI's dichotomy when conducting a cluster analysis and they found very limited empirical support for Holmes typology. Other studies have also failed to find empirical evidence for the efficacy of the typologies (Canter, Alison, Alison, & Wentink, 2004; Canter & Wentink, 2004; Canter & Young, 2009).

Not only has research been conducted on the empirical efficacy of these typologies, but there are also studies on the perceived and actual accuracy of profilers. Research conducted on the accuracy of profiling range from case studies to more rigorous research studies. There have been many books that present semibiographical case studies, while these studies are not enough to look at alone they do provide an important lens to look at criminal profiling through. Many of the research studies that attempt to determine

the accuracy of profilers use post hoc assessments. The majority of these studies use the detective's opinions on the profiles they have received as the basis for the utility of these profiles. These studies are limited because they rely on the subjective opinions of the investigators after the case has been closed. However, these studies did discover that the majority of the detectives found the profiles useful in varying ways and they approved of the advice (Alison et al., 2002). In a more rigorous research study a meta-analysis was conducted, the researchers compared the accuracy of self-labeled profilers/experienced-investigator groups to a comparison group of all other groups included in the studies, such as detectives and students. They looked at the outcomes for predictability of the overall offender, cognitive processes, physical attributes, offence behaviors, and history/habits and found that the profiler groups were not more accurate than the comparison groups, in some instances the profiler group performed worse than the comparison group. The only facet in which the profiler group performed better than the comparison group was predicting the overall offender outcome[2], with an accuracy rate of 62% and 38% respectively (Snook et al., 2007). More recent studies have shown that profilers are able to competently identify characteristics of unknown offenders (Kocsis & Palermo, 2015).

Statistical Typologies of Serial Murderers

Statistical approaches to profiling are rarely used, not only for serial murderers, but also for other crimes where profiling is used (e.g. arson, sexual assault, and

[2] Overall offender outcome includes four submeasures: cognitive processes, physical characteristics, offense behaviors, and social history and habits (Snook et al., 2007).

pedophilia). These statistical approaches are rarely used because the types of analyses that would be estimated to create typologies are still fairly new to the field of criminology and take a specialized knowledge of the analysis. Canter et al. (2004) created a typology from data they used to test the validity and reliability of the FBI's dichotomy. They used a multi-dimensional scaling procedure known as smallest space analysis to create a radex model of criminal actions. The radex model splits these actions into four sections of interaction types with victims: *Execution*, *Plunder*, *Sexual Control*, and *Mutilation* (Canter, 2011). The *Execution* section had the least amount of actions with only five including throat cut, manual strangulation, victim burned, multiple sex acts, and firearm used. In the *Plunder* section there were seven actions some of them were beaten, overkill, bludgeoned, and belongings scattered. *Sexual Control* had fourteen actions such as rape, posed body, multiple crime scenes, and isolated location. The last section, *Mutilation*, had thirteen actions some of them were missing weapon, tampered evidence, object penetration, and mutilations of various kinds. Although this may be an initial effort in statistical typology profiling, it has yet to be tested by other researchers and is not used widely (if at all) by police officers or other researchers.

Much of what is observed on criminal profiling is a clinical approach, where researchers and investigators use their past experiences, intuition, and knowledge to develop typologies and provide assistance in investigations. Criminal profiling is viewed as another tool in police officers belts to lead them in the right direction in finding an offender. However, multiple studies have shown that there is little to no support for these practices and that their use can be redundant (Canter et al., 2004; Snook et al., 2007;

Taylor et al., 2012). If criminal profiling shifted to a statistical approach it could be more useful for law enforcement and researchers because the assistance provided by this method would be more reliable and valid. Up until this point there has only been one study approximating an empirical approach, but there have been no follow-up studies testing its validity or reliability to date (Canter et al., 2004). There are countless clinical typologies with many studies questioning their empirical efficacy, while the field is severely lacking empirical studies. In order to transition criminal profiling from anecdote-based work relying on intuition, into a more reliable and effective tool in understanding and apprehending serial murderers, quantitative research must be conducted to identify typologies with the support of scientific evidence and useful predictive capabilities.

Present Study

Criminal profiling is an emerging approach with great potential for assisting in law enforcement efforts in solving crime, but there is a conspicuous gap in the methodology of the studies in the area focusing on serial murderers. The majority of studies approach profiling through a clinical lens, and when they are empirically tested there is little, if any, evidence supporting their validity (Canter & Young, 2009; Snook et al., 2007; Taylor et al., 2012). With this in mind, this research study attempts to fill this gap by introducing a statistical approach to the study of profiling serial murderers. This research relies on an approach that combines the clinical and statistical approaches by empirically testing whether the salient factors in the clinical approach are statistically significant in the statistical approach. Bringing in these concepts from the qualitative research that has already been conducted allows the typologies to be tested statistically

while also looking at other characteristics that could be pertinent to creating a typology. The main contribution of this research is that it aims to investigate other typologies before contributing a new typology. In addition, this study examines the homology assumption and tries to determine if there are background characteristics that are inherent to criminal behaviors.

The statistical approach to offender profiling has yet to become a popular method because of the specialization and in-depth knowledge it takes to perform these analyses that will allow a study to create a typology. There is also an issue of accessing data that will allow for quantitative analyses. It would take a long time to collect enough data to conduct quantitative analyses and it would be very difficult to find the opportunities to collect this type of data. Collecting data on serial murderers would involve many different law enforcement agencies because very few departments have apprehended multiple serial murderers. This is why the present study is using data from a secondary source. However, using previously collected data also has issues because you are not able to control what information about the perpetrator is provided, which can make it extremely difficult to perform these analyses especially if you want to look at a few key variables. Using quantitative analyses to create new typologies for serial murderers provides an opportunity to increase the utility of these techniques as a law enforcement aid.

METHODOLOGY

Sample and Data

Data for this research study were obtained from the Radford University/Florida Gulf Coast University database on serial murderers, which also includes data on spree killers and mass murderers (Radford/ FGCU Serial Killer Database Research Project, 2015). With 4,068 subjects, 11,680 victims, and 175 variables ranging from demographics to information about the crimes (Aamodt, 2015), this database provides a unique opportunity to investigate a large number of serial murderers through empirical means. The project used subjects that were classified as serial killers, killing three or more victims, and subjects who had killed in the United States. The total number of subjects used for this study based on the above described criteria was 1,131. Maximum likelihood estimation was used with the missing data because there were very little missing data and the data was missing at random meaning there was no systematic difference in the data that was missing versus the data that was not. Using Maximum likelihood estimation allowed expected values to be determined (Kline, 2005), thus maintaining the number of subjects at 1,131. The information in this database was obtained through public sources, such as court documents and websites. Sources were also provided to assess the validity of the data.

Descriptive statistics were estimated on the 175 variables to determine how much missing data was present for each variable, and which would be the most appropriate to use in the analysis. Many of the variables pertaining to the psychology of the subject had

large amounts of missing data. Out of the 175 variables, 23 of the variables in the dataset were determined to have enough responses and be relevant for the study. Variables were determined to be relevant if they were about the crime, crime scene, or background characteristics, and were from previous research or clinical uses. There were many variables that presented the same information in different forms, such as the age of first kill and the age of group of first kill. The majority of variables were not included due to the amount of missing data.

Measures

There are many variables in this dataset that could be used in the analysis; however, the project used five variables to perform a preliminary analysis before adding in the others. These five discrete variables that were used in the preliminary analysis to determine if there are underlying classes among serial murderers were: the number of victims, the victim's sex, if the offender killed with their hands, the victim's race, and if the offender raped the victim. The variable number of victims was left as a continuous variable to allow for more variation. Originally the project binned the variable[3] making it a categorical variable, however since the data were skewed the results pooled in certain areas due to this one variable. The victim's sex is a dummy variable, coded 1 for male and 2 for female[4]. The variable killed with hands is coded 1 for "yes" and 2 for "no". The victim's race is a categorical variable that originally had seven categories, but there were only a few cases in many of the categories, the researcher decided to collapse these

[3] In r different numbers were assigned to the variable based on the number of victims. The ranges for the bins were 3, 4-7, 8-11, 12-15, 16-19, and 20+.

[4] All dummy variables were recoded 1 and 2 because when performing a latent class analysis in Mplus variables cannot be coded 0.

variables, and coded 1 for White, 2 for Black, and 3 for Other. The last variable, rape, was coded 1 for "yes" and 2 for "no". The descriptive statistics for these five variables are presented in Table 1 and 2. The categorical latent variable in the models analyzed for this latent class analysis, are the theoretical underlying classes.

Analysis

A latent class analysis (LCA) will be used to determine if there are underlying clusters of serial murderers. LCA "can be considered a qualitative data analog to factor analysis which enables researchers to empirically identify discrete latent variables from two or more discrete observed variables.", but the difference being that LCA uses categorical variables instead of continuous variables. (McCutcheon, 1987). Compared to other analyses that could be used, such as cluster analysis, LCA is methodologically stronger and does not make the assumption that the clusters exist but rather tries to determine if there are any typologies that do exist. LCA is a type of structural equation modeling (SEM), which refers to a collection of statistical tests that have shared characteristics. Most SEM statistical tests use continuous variables; however, there is a grouping of tests that use categorical latent variables that are referred to as classes. A latent class is a variable indicating underlying subgroups of individuals based on observed characteristics. Membership in the subgroup is said to be "latent" because membership in a class cannot be directly observed. There are also mixture models, including LCA, which have a combination of continuous and categorical latent variables, which are becoming more widely used. However, in certain computer programs, such as

Mplus (Muthén & Muthén, 2007), make it difficult to distinguish between these different analyses (Kline, 2005).

There are many statistical techniques related to LCA, ranging from factor analysis to cluster analysis, but with the data collected for this study, LCA had many advantages over these other statistical techniques. One of the advantages of using latent variable modeling is that it does not rely on linearity and normality, which are common assumptions that are easy to violate. Some of the other techniques rely on distance or ad hoc probabilities to determine goodness-of-fit indices and form maximum likelihood derived classes, while LCA relies on person-based or case probabilities. The final class solutions derived from these latent class models are entirely dependent on the variables originally entered into the model (Vaughn, Delisi, Beaver, & Howard, 2008).

The most appropriate analysis to use for this study is a LCA. This categorical analysis provides a unique opportunity to group subjects into categories. This LCA assumes that a certain number of distinct pathways of serial murderers exist, and subjects can be grouped into latent classes based on background and crime scene characteristics, with each subject belonging to one cluster. The aim of LCA is to account for all the associations between variables with the smallest number of clusters. Cluster-specific probabilities given membership in that cluster for variables allow profiles of serial murder to be developed for subjects in each cluster (Dunn, Jordan, & Croft, 2006). The null hypothesis for this study is that multiple latent classes of serial murderers do not exist, and there is only one latent class for serial murderers. The alternative hypothesis is

that multiple latent classes of serial murderers do exist and there is more than one latent class for serial murderers**.**

There are two types of latent class analysis that can be conducted: a confirmatory latent class analysis or an exploratory latent class analysis. In a confirmatory latent class analysis, the researcher would begin the study with a theory, and use this theory to determine what variables are used and how they interact. Their hypothesis would then be that the model the theory supports exists or it does not exist. However, an exploratory latent class analysis was used in this research study because the literature does not present a strong theory about the nature of the classes, rather they believe several measures are part of a complex *s*ystem and want to explore the relationship (McCutcheon, 1987).

There are many platforms capable of performing LCA, but for this study will rely on Mplus. The study is using Mplus because it has different add-ons that allows the researcher to perform mixture models, which use continuous and categorical variables (Kline, 2005; Muthén & Muthén, 2007). This program also provides predictive fit indexes, which assists the researcher in determining whether a model with more classes or less classes is appropriate through assessing model fit. Two of the predictive fit indexes used are the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC), these are used to compare nonhierarchical models[5], with lower values indicating better model fit. However, there is a balance to choosing the best model because as the AIC and BIC go down, some of the other values may increase, such as the

[5] Nonhierarchical models are two models that are explaining the same latent class, but are not a subset of one another (Kline, 2005).

degrees of freedom, which is not favorable either. Latent class models start with a one-cluster model, which would be the case if all subjects have the same pathway to serial murder, then each consecutive model adds another cluster. To determine the optimal number of clusters this study will investigate the previously mentioned model fit indices (Dunn, Jordan, & Croft, 2006).

RESULTS

A one- through five-class model was estimated to determine if there are multiple latent classes of serial murderers. When investigating the one-class model and the two-class model results it is evident that there is improved model fit in the two-class model by looking at the model fit indices, which indicates that there is more than one latent class of serial murderers. Since there is more than one latent class this means that the null hypothesis can be rejected. Once the researcher was certain there was more than one latent class the focus shifted to the number of classes that best fit the data.

Results of the three- and four-class estimates are displayed in Table 4 and 5. Included in Table 4 are the entropy values, which range from 0 to 1. Greater class separation and homogeneity occur the closer the values are to 1. This indicates that the higher entropy levels assess the distinction of class solutions and relative “purity”. When comparing the AIC and BIC values recall that the lower the values represent better model fit compared to higher values of other models. The four-class solution shows the best fit to the data because of the higher entropy value and the improved AIC and BIC values, which indicated an improved model fit. Included in Table 5 is the four-class solution posterior class assignment probability. The quality of this classification is also high because of the high diagonal values see in Table 5.

Figure 1 and 2 illustrates the three and four-class solution. The three-class solution represents a number of victims gradient ranging from low (class 1 and 2) to high (class 3). The main divide between these three classes were the amount of victims and

whether the victim had been raped or not. The second class consisted of the group of rapists while the first class was primarily non-rapists and the third was split down the middle. Except for the third class the majority of the estimates for the other two classes were statistically significant. In the four-class solution the same pattern with rape occurs as the three-class model, with the majority of the cases clustering in two of the classes. This solution represents a number of victims gradient ranging from low (class 1 and 4) to medium (class 3) to high (class 2). The estimates for the first and the fourth class were statistically significant, but the other two classes were mostly not significant. In both of these models the classes that were statistically significant were the classes that had the rapist and non-rapist groups.

Table 6 lists the mean scores for each class. The majority of covariates for class 1 and 4 were statistically significant, which are the classes that differentiate between rapists and non-rapists. Since the majority of the sample are in these two groups it is expected for them to be statistically significant. Multiple covariates in class 3 and 4 were not statistically significant, but this is not unusual with only 1.3% and 4.7% of the sample being in each class respectively.

Class 1: Low kill rapist. Offenders in this group most often raped their victims and killed the victims with their hands. The offenders tended to kill fewer victims and the victims tended to be White females. This cluster consisted of 46% of the offenders. *Class 2: High kill.* Offenders in this group most often did not rape their victim and killed the most victims out of all the clusters. A little over half of the offenders in this cluster killed victims of both sexes and killed the victims with their hands. The race of the victims in

this cluster was evenly split between White and Other. Only 1% of the offenders were in the second class. *Class 3: Medium Kill.* The only variables that stood out in this cluster were that the offender tended to kill with their hands and they killed in the middle of the range. Only 4% of the offenders were in the third class. *Class 4: Low kill non-rapist.* Offenders in this class most often did not rape their victim and killed fewer victims. The majority, 47%, of offenders were in this fourth cluster. The probabilities for the variables in each class are presented in Table 3.

Multiple model fit indices, which are listed in Table 4, were investigated to determine the number of classes that best fit the data. Based on these different model fit indices it was determined that the four-class model fit the data the best. However, the majority of the sample went into two classes for both of the models that had been estimated, and these classes were the high and low rape groups. Since most of the data were in these two classes and these were the classes that were statistically significant it becomes apparent that there is a major divide between whether the offender raped the victim or not that supersedes all other variables.

DISCUSSION

With a large sample of 1,131 serial murderers, classified as killing three or more victims in the United States this study creates an empirically based taxonomy. Through the use of an exploratory latent class analysis these data indicate that there is a systematic difference between rapist and non-rapists. This divide became apparent when multiple models were analyzed including a wide range of variables, but the separation in classes was due to the rape variable. Also the models described in the results illustrate this divide by the classes including rapists and non-rapists being the ones that were statistically significant. Another variable that showed variation between the different classes was the number of victims. In the three-class solution there were only a high and low kill group, but in the four-class solution a medium kill group emerged. This pattern was also evident in some of the other models that were estimated, but not as prominent as the divide between rapist and non-rapist.

The systematic difference between rapists and non-rapist led the researcher to perform a LCA with these two groups separated out. The idea behind analyzing the groups separately is that these two groups are fundamentally different and that they have their own classes for each group that are not compatible. However, when these two models were analyzed comparing multiple variables the separation was not as prominent. This could be caused by not including the appropriate variables to distinguish different classes.

Other models were estimated in order to look at background characteristics, crime scene characteristics, and well-known typologies. The Holmes typology and FBI dichotomy were investigated, and neither of them had good model fit. Since the data was a secondary source there were some aspects of these typologies that were not captured in the data set used in this study indicating that these results are not very conclusive. The models that included only the background characteristics and crime scene characteristics showed some promise. However, the model with the best fit was with the original model discussed in the results section showing a divide in rapist and non-rapist.

Implications

The results of this study have important implications for criminal profiling theory as well as applications in law enforcement. First, this study furthers research on profiling by taking the insights from clinical approaches to profiling and performs statistical analyses to test their validity. The majority of profiling typologies are based on a law enforcement official's past experiences, and the criminal justice field has started to question the utility of these studies because of well publicized blunders. There have also been a few studies testing the most well-known typologies in the field, and finding little support for them. This study has introduced an approach to profiling that will circumvent these criticisms while providing an empirically sound, but clinically driven typology. Second, this study makes empirical profiling a more useful arsenal in the belts of law enforcement by helping them solve crimes. Law enforcement tends to focus on elements, such as paraphilias and totems, which were not very prominent in the large dataset used for this study and the utility of which is questioned. This could be due to the fact that the

media sensationalizes these elements, but they are really not important when trying to apprehend serial murderers because they are so rare. By guiding law enforcement to spend their time and resources focusing on whether the offender raped the victim or not and other variables associated with this, more of these crimes could be solved because time will be spent focusing on these relevant factors instead of the sensationalized ones. A form can be created using these background characteristics to provide law enforcement with a decision tree enabling them to classify which typology the offender belongs in. This standardized method allows for a way to evaluate the typology when being used in practice. Eventually this method could also be extrapolated to other crimes, such as arson and rape. This study does not aim to replace investigative techniques used, but instead add to the ones already used by law enforcement.

Limitations

Although this study uses data from a large dataset with multiple reliable sources that were fact checked, there are still potential issues with data used from a secondary source. When using secondary sources, the researcher has no control over what variables are in the dataset. This study might have been able to create a more thorough typology if access to other variables was available. In profiling there is a strong emphasis on the psychological factors of the offenders, but the majority of the psychological variables in this dataset had too much missing data to be used in this analysis. Not including psychological variables in this study limited how well the researchers could test past typologies and whether homology exists among serial murderers. In part, this study conducted an exploratory latent class analysis because of the limitations in what variables

were available. If this study had access to original data, it would have been more plausible to perform a confirmatory latent class analysis because theory could drive what variables data were collected on.

Another limitation of this study is that these data were mostly drawn from open sources. While these sources were found to be reliable, using police records would have allowed for more detailed information about the crimes and crime scenes to be collected. Also, using different sources for the same database makes it difficult to collect the same information for each offender and the accuracy of the data can be difficult to determine. Even if only police records or government documents were used there is still a question of accuracy because police officers are inferring how the crime took place and the motivation of the offender.

With data being collected on any type of crime there is always a question of under or over-reporting that may skew the results of an analysis. One way serial murderers may be under-reported is because this dataset can only provide information on serial murderers who have been detected. Under-reporting may also be an issue with the number of victims. An example of this is that law enforcement who have apprehended a serial murderer may not have discovered all of the murders they have committed. These victims may not be counted in the dataset depending on the sources the information was collected from. Under-reporting can also be an issue because some serial murderers have so many victims they do not remember how many victims they have. Over-reporting can be an issue with serial murderers too because they are known to exaggerate the amount of victims they have. Since these data were not collected by police reports the suspected

offender might have been falsely accused and were never prosecuted, which would be an over-reporting issue for the number of serial murderers.

Since there is no consensus on the definition of serial murderers it is very difficult to compare results across studies. This has also made it difficult to determine how to classify an offender as a serial murder in this study, as opposed to a mass murder. Having limited data on the time frame of the offenses restricted how accurate the classification of serial murder was in this study. However, many of the definitions no longer emphasize time frames of the offenses.

Future Research

While research involving the profiling of offenders has come a long way since its inception there are still many improvements that could be made. The next step with this line of research is to collect more extensive data on serial murderers. By introducing more reliable and accurate data, more light might be shed on the type of offenders that exist. This study has shown that there is a systematic difference between serial murderers who rape their victims and the ones who do not. In future research introducing variables that are theoretically related to why an individual would rape a victim would further test these conclusions. Also including factors that are known to affect future rape offense patterns such as childhood sexual victimization could help with this. Having more data on areas such as past criminal histories would also allow researchers to draw more empirically sound conclusions on the typologies they are creating. Introducing psychological and personality factors on the offenders will allow researchers to test some of the main assumptions made by profilers. Interviewing serial murderers would provide

an abundance of useful information on the makeup of these offenders that is not possible to gather from police records and public sources.

Additionally, this empirical approach could be used to analyze other types of crimes not explored in this study. By examining the behaviors of offenders in other types of crimes it would make it possible to compare the types of offenders who commit one type of crime versus another. Comparing typologies of crimes provides the opportunity to determine if there are similar behaviors committed by offenders in different crimes.

Criminal justice professionals and the public tend to have a mental mindset of what a serial murderer is, but with the shift in definitions there are many offenders who would be classified as a serial murderer even though they do not fit into this mental mindset. For future research to be as useful as possible there needs to be a standard definition of serial murderers that allows for more reliable data to be collected. This definition should also be used in law enforcement, which would allow law enforcement to compare crime rates and give researchers the opportunity to conduct studies more easily.

Conclusion

The public, media, and law enforcement have been fascinated with serial murderers since the 1980s, which has led to an increase in fictional stories and research (Snook et al., 2007). One area within serial murder research that became very popular was criminal profiling. However, it has started to fall out of favor within the research community and law enforcement agencies because of well publicized blunders (Aamodt, 2008; Woodworth & Porter, 1999). The investigations that have led to this decline have

used a clinical approach to profiling, which involves the expert's intuition, training, knowledge, and past experience to determine what traits the offender possess. Research in offender profiling has started to turn to statistical approaches, which use statistical analyses to determine if there are any similarities between offenders in order to create typologies (Snook et al., 2007). There have only been a few studies testing clinical typologies through statistical methods and even fewer studies have created statistical typologies, with none of them being conducted on serial murderers (Canter et al., 2004; Snook et al., 2007; Taylor et al., 2012).

The majority of literature involving serial murderers focuses on the offender's motivation, whether the offender took a totem, and if the offender participated in any paraphilias such as if the offender mutilated the body or participated in necrophilia. However, the majority of the cases in the dataset used for this study did not participate in these types of behaviors. Since past research has struggled to validate the utility of these factors, the current study takes an exploratory approach to investigate a wide range of alternative factors. By performing an LCA on such a large dataset this study has helped move offender profiling to a more empirical approach. The LCA uncovered that with the majority of the models that were analyzed the divide between classes were mostly due to the rape variable. The number of victims also had a bigger impact than the other variables, but it was not as definite as the rape variable. Other models were estimated with the dataset split into two based on whether the victim was raped or not, but the divide was lost in these later models. This could be due to not having the appropriate variables to uncover whether there are different classes among serial murderers. Future

steps for this project would include collecting data on psychological factors and past crimes committed by the offender.

Statistical methods of research have become more prominent in social science research recently. However, this shift in research has yet to reach offender profiling. This study adds to these efforts by using a statistical analysis to investigate serial murderers. The methods used in this research study could also be applied to other crimes in order to create more data driven typologies. While there were limitations to using secondary data this study provided an important first step to a statistical approach and has many important implications for profiling theory.

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APPENDIX A: TABLES and FIGURES

Table 1: Background Characteristics

Background Characteristics			
Offender	Sample %	Victim	Sample %
Gender		**Gender**	
Male	91%	Male	18%
Female	8%	Female	35%
		Both	46%
Race		**Race**	
White	55%	White	54%
Black	38%	Black	16%
Other	6%	Other	29%

Source: Radford/FGCU Serial Killer Database Research Project (2015)

Table 2: Crime Scene Characteristics

Crime Scene Characteristics				
	Sample %	M	Range	N
Killed with Hands	66%			1,089
Raped the Victim	42%			1,075
Number of Victims		5.962	3-49	1,131
Age of First Kill		27.69	9-72	1,066

Source: Radford/FGCU Serial Killer Database Research Project (2015)

Table 3: Class Probabilities

	Class 1: Low Kill Rapist	Class 2: High Kill	Class 3: Medium Kill	Class 4: Low Kill Non-Rapist
No. (%)	520 (46)	15 (1)	54 (4)	541 (47)
Rape				
Yes	0.818	0.269	0.599	0.033
No	0.182	0.731	0.401	0.967
Victim Sex				
Male	0.045	0.200	0.263	0.31
Female	0.716	0.132	0.211	0.023
Both	0.239	0.669	0.526	0.666
Killed with Hands				
Yes	0.927	0.668	0.718	0.408
No	0.073	0.332	0.282	0.592
Victim Race				
White	0.572	0.469	0.331	0.547
Black	0.162	0.083	0.045	0.177
Other	0.266	0.421	0.623	0.276

Source: Radford/FGCU Serial Killer Database Research Project (2015)

Table 4: Model Fit Indices

Number of Classes	LL	AIC	BIC	Npar	df	LRT p-value	Entropy
3	-6288.26	12624.53	12745.27	24	83	0.3130	0.84
4	**-6083.56**	**12231.12**	**12392.11**	**32**	**83**	**0.0004**	**0.87**

The bold represents that the 4-class solution was the best fit to the data.
LL=Loglikelihood
AIC= Akaike Information Criterion
BIC= Bayesian Information Criterion
Npar= number of parameters
LRT= Lo-Mendell-Rubin Adjusted LRT Test

Table 5: Class Assignment Probability

	Class 1	Class 2	Class 3	Class 4
Class 1	0.950	0.000	0.002	0.048
Class 2	0.000	0.999	0.001	0.000
Class 3	0.010	0.002	0.960	0.029
Class 4	0.076	0.000	0.002	0.921

Source: Radford/FGCU Serial Killer Database Research Project (2015)

Table 6: Class Mean Scores

Indicator Variables	Class 1	Class 2	Class 3	Class 4
	N=503 M (SE)	N=15 M (SE)	N=54 M (SE)	N=559 M (SE)
Rape	1.503 (0.173) ***	-0.999 (0.592)	0.401 (0.318)	-3.385 (0.585)***
Victim Sex				
Male	-3.053 (0.263) ***	-1.388 (0.643) *	-1.029 (0.346) **	-0.798 (0.106)***
Female	1.159 (0.140) ***	-0.702 (0.547)	-0.105 (0.291)	-0.691 (0.103)***
Killed with Hands	2.547 (0.250) ***	0.697 (0.554)	0.934 (0.323) **	-0.371 (0.103)***
Victim Race				
White	0.209 (0.104) **	-0.016 (0.578)	-0.702 (0.300) *	0.187 (0.101)
Black	1.017 (0.115) ***	0.318 (0.582)	-0.503 (0.292)	0.963 (0.111)***
Number of Victims	4.739 (0.107) ***	39.219 (1.480) ***	18.929 (1.016)***	4.914 (0.118)***

*p<0.05 **p<0.01 ***p<0.001

Source: Radford/FGCU Serial Killer Database Research Project (2015)

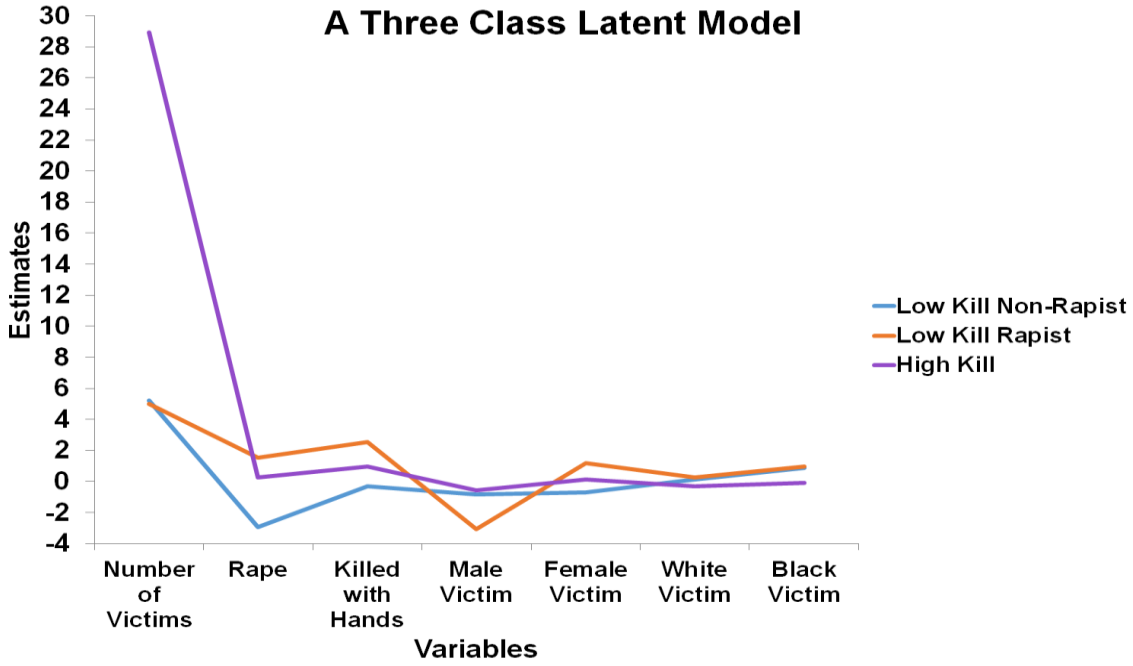

Figure 1: Three Class Model

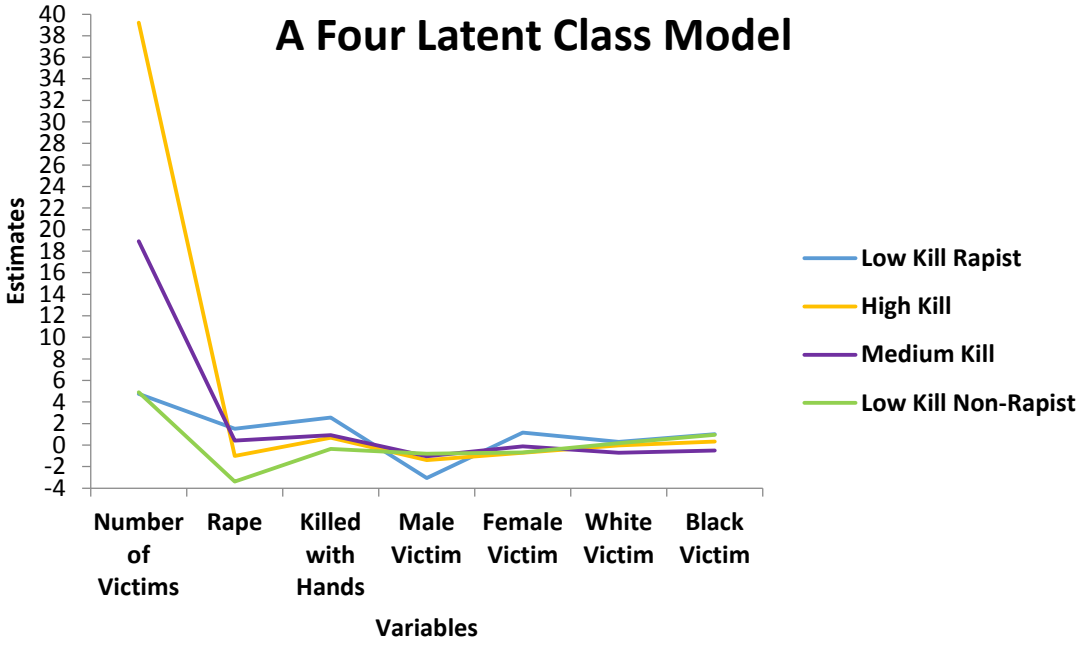

Figure 2: Four Class Model