

https://dspace.org/

The Behaviour Consistency of Serial Murder Offenders in South Africa

McGivern, Kelly Berene

2025
University of the Witwatersrand, Johannesburg
https://hdl.handle.net/10539/49992
McGivern, Kelly Berene. (2025). The Behaviour Consistency of Serial Murder Offenders in South Africa [PhD thesis, University of the Witwatersrand, Johannesburg]. WIReDSpace. https://hdl.handle.net/10539/49992

Downloaded from a DSpace repository. https://dspace.org/

THE BEHAVIOUR CONSISTENCY OF SERIAL MURDER OFFENDERS IN SOUTH AFRICA

Kelly Berene McGivern

751579

A Thesis submitted to the Faculty of Heath Sciences, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Doctor of Philosophy.

Supervisor: Professor G.N. Labuschagne (PhD), University of the Witwatersrand

Johannesburg, 2025

Division of Forensic Medicine and Pathology
School of Clinical Medicine
Faculty of Health Sciences
University of the Witwatersrand

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

DECLARATION

I **Kelly McGivern** (Student number: **751579**) am a student registered for the degree of **Doctor of Philosophy** in the academic year **2025.**

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I have used the Harvard ~~or Vancouver~~ referencing style in this ~~assignment/research report/dissertation~~/thesis.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix (Appendix A) a report from "Turnitin" (unless automated during submission to Ulwazi) indicating the level of plagiarism in my research document.

GENERATIVE ARTIFICIAL INTELLIGENCE (GAI) DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

- I acknowledge that using generative AI tools without explicitly disclosing their use is considered a form of plagiarism and is classified as academic misconduct by Wits University.
- I hereby declare that in the completion of coursework or research for my degree, or in the preparation of this ~~assignment/research report/dissertation/~~thesis (tick the relevant option):

☐ I **did not** use GAI tools or platforms

☒ I **did** use GAI tools or platforms as follows (tick all that apply):

1. ☐ Idea Generation – Used GAI to brainstorm research topics, research questions, or key concepts.
2. ☐ Literature Exploration – Used GAI to identify relevant research areas, summarize academic sources, or suggest key authors.

3. ☐ Writing Assistance – Used GAI for drafting, paraphrasing, summarizing, or improving the clarity of sentences.
4. ☒ Grammar and Style Enhancement – Used GAI for grammar, spelling, punctuation, or stylistic refinement.
5. ☒ Referencing – Used GAI to generate citations, format references, or check adherence to style guides.
6. ☒ Code or Data Analysis – Used GAI to generate, debug, or explain code, analyse data, or interpret statistical results.
7. ☒ Table and Figure Generation – Used GAI to create structured tables, graphs, or visual summaries of data.
8. ☐ Feedback and Revision – Used GAI to provide suggestions for improving argumentation, structure, or coherence.
9. ☐ Translation and Language Support – Used GAI to assist with translation or improve academic writing in a non-native language.
10. ☒ Other (state details): Mendeley, IBM SPSS Statistical Software, DATAtab and MedCalc were used.

Tick the relevant option:

☒ I **did** review and modify the above-mentioned GAI outputs.

☐ I **did not** review and modify the above-mentioned GAI outputs.

NOTE: The actual GAI chat may be added in the appendix.

Signature:  Date: 16th September 2025

Dedicated to my parents,
Daphne and Sean McGivern

&

My dear friend,
Angela Pitter (1988 - 2014)

ABSTRACT

In serial murder investigations lacking forensic evidence, investigators need valid and reliable ways of linking crimes committed by the same offender. The underlying principles of crime linkage are based on the observed consistent, yet unique behaviours, demonstrated by offenders across crimes. The purpose of crime linkage is to assist in investigations by identifying whether two or more crimes are likely to have been committed by the same offender, and provide similar-fact evidence in legal proceedings, connecting crimes at trial even when forensic or other evidence only partially links an offender to a series of crimes. This study examined behaviour consistency and distinctiveness among serial murder offenders in South Africa using solved and unsolved (yet forensically linked) murder series. The study aimed to empirically test the underlying principles of crime linkage research using an ecologically valid sample. The study's novel approach of including unsolved murder series addresses limitations and criticisms regarding the ecological validity and reliability of previous crime linkage research. Data were collected from original case files of the South African Police Service's (SAPS) Investigative Psychology Section (IPS), and a sample of 21 murder series with a total of 126 victims was identified. Crime scene behaviours were coded using a binary system to indicate presence (1) or absence/missing (0) of a behaviour. Jaccard's coefficient was used to measure similarity of crime pairs quantitatively. Results indicated that linked crime pairs were significantly larger than unlinked crime pairs, across all datasets. Binary logistic regression analysis with resulting Receiver Operating Characteristic (ROC) and Area Under the Curve (AUC) indicated effective discrimination accuracy between linked and unlinked crime pairs when all crime scene behaviours were considered (AUC = 0.87). While the study found support for the underlying principles of crime linkage, it also revealed variability among offenders' behaviour. Behavioural domains influenced by victim-offender interaction proved less effective at differentiating between linked and unlinked crime pairs. Future research should focus on refining the operationalisation of crime scene behaviours to improve linkage accuracy. By using original police case files and incorporating unsolved series, this research strengthens the ecological validity and reliability of crime linkage research, providing valuable insights for investigative and legal contexts.

Key words: crime linkage, serial murder, behavioural consistency, behaviour distinctiveness

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to the South African Police Service (SAPS) Investigative Psychology Section (IPS) for their cooperation and assistance in facilitating this research. In particular, I would like to thank Lieutenant Colonel Elmarie Myburgh for coordinating access to case files as well as her unwavering kindness, patience, and guidance in order for me to collect the data needed for this study. I am also grateful to members of the Section: Brigadier Thusi, Lieutenant Colonel Jan De Lange (RET), Captain Bronwen Hall, and Captain Naomi Griffiths for their assistance in case identification and docket verification.

I am particularly grateful and indebted to Professor Jessica Woodhams for her invaluable statistical expertise and guidance, which was instrumental in enabling me to conduct data analysis. I would still be staring at my computer if it had not been for her direction, patience, and willingness to assist me. Additionally, I would like to thank Professor Craig Bennell for his willingness to assist the research study by kindly sharing his B-LINK software program with me.

Completing this PhD would not have been possible without the support, love, and encouragement from my wonderful family, friends, and especially my partner, Wayne. Thank you for challenging me and believing in me. Your patience and constant support helped keep me motivated and sensible (enough) through this process. Thank you, Mom, for your unconditional love, support, and for helping me to simplify and formulate my thoughts through all your proof reading. Thank you, Dad, for your steadfast encouragement.

A special thank you to my colleague and wonderful friend, Dr. Gregory Mitchell for his continuous encouragement, motivation, intellectual advice, and unwavering support.

Lastly, I am most grateful for the patience, guidance, feedback, and expertise of my supervisor, Professor Gérard Labuschagne. It has been an honour to have had you as my supervisor and mentor on this longer-than-planned journey. Having access to your experience and knowledge has been invaluable to this research study as well as my learning experience. I am hopeful that this is the beginning of many fruitful collaborations to come.

TABLE OF CONTENTS

DECLARATION ..... **II**
ABSTRACT ..... **V**
ACKNOWLEDGEMENTS ..... **VI**
LIST OF FIGURES ..... **XII**
LIST OF TABLES ..... **XIII**
NOMENCLATURE ..... **XIV**

CHAPTER 1
INTRODUCTION

1.1 CHAPTER PREVIEW **1**
1.2 RESEARCH CONTEXT AND BACKGROUND TO THE STUDY **1**
1.3 RESEARCH PROBLEM STATEMENT **3**
1.4 PRIMARY AIM AND OBJECTIVES OF THE RESEARCH **4**
1.5 SCOPE OF THE STUDY **6**
1.6 SIGNIFICANCE OF THE STUDY **6**
1.7 DEFINITION OF KEY TERMS **7**
1.7.1 Area Under the Curve **7**
1.7.2 Correct Rejections **8**
1.7.3 Crime Linkage **8**
1.7.4 Criminal Profiling **8**
1.7.5 False Alarms (FA) **8**
1.7.6 Hits (H) **9**
1.7.7 Jaccard's Coefficient **9**
1.7.8 Linked Status **9**
1.7.9 Misses **9**
1.7.10 Murder Series **9**
1.7.11 Receiver Operating Characteristic **10**
1.7.12 Threshold **10**
1.8 OUTLINE OF THE STUDY **10**
1.9 CHAPTER CONCLUSION **11**

CHAPTER 2

LITERATURE REVIEW

2.1 CHAPTER PREVIEW 12

2.2 SERIAL MURDER: A MORBID CURIOSITY 12

2.2.1 Brief History of the Term and Prevalence of Serial Murder 13

2.2.2 Definitions of Serial Murder 16

2.2.3 Criticism and Limitations of Definitions 18

2.2.3.1 Victim Count 18

2.2.3.2 Cooling off Period 20

2.2.3.3 Motive 21

2.2.3.4 Victimology/Stranger Victims 22

2.2.3.5 Linked Murders 23

***2.2.4* Definition Used in this Study 23**

2.2.5 Serial Murder Classification Systems 24

2.2.5.1 Organised, Disorganised, and Mixed Typologies 25

2.2.5.2 Holmes and Holmes Motivation-based Typology 26

2.2.5.3 Keppel and Walter's (1999) Classification System 28

2.2.5.4 Instrumental and Expressive Murders 29

2.2.6 Serial Murder in South Africa 30

2.2.6.1 Studies of Serial Murder in South Africa 31

2.2.6.2 Victims, Offenders, and Offence Characteristics 32

2.3 CRIMINAL PROFILING: BEHAVIOURAL EVIDENCE ANALYSIS 35

2.3.1 Criminal Profiling in South Africa 40

2.4 CRIME LINKAGE 41

2.4.1 Theoretical Assumptions: Behaviour Consistency and Distinctiveness 42

2.4.1.1 Victimology 44

2.4.1.2 Modus Operandi 46

2.4.1.3 Fantasy and Ritual 48

2.4.1.4 Signature 49

2.4.1.5 Spatial Patterns and Crime Proximity 50

2.4.2 The Importance of Crime Linkage 51

2.4.2.1 The Investigative Phase 53

2.4.2.2 The Trial Phase 54

2.4.3 Crime Linkage Research 56

2.4.3.1 Empirical Studies Linking Serial Murder Based on Behaviour Consistencies.. 59
2.4.4 Methodologies Used to Test the Underlying Principles of Crime Linkage..... 62
2.4.5 Empirical Tests of Crime Linkage..... 65
2.4.6 Difficulties and Limitations of Crime Linkage..... 71
2.4.6.1 Practical Limitations..... 71
2.4.6.2 Limitations of Previous Crime Linkage Research..... 72
2.5 RESEARCH GAP AND NEED FOR THE CURRENT STUDY 76
2.6 CHAPTER CONCLUSION 77

CHAPTER 3
RESEARCH METHODOLOGY

3.1 CHAPTER PREVIEW 78
3.2 RESEARCH DESIGN AND PROCEDURE..... 78
3.2.1 Ethics Approval..... 78
3.2.2 Research Approach..... 78
3.3 SAMPLING..... 78
3.4 DATA COLLECTION..... 82
3.4.1 Data Reliability..... 85
3.4.1.1 Interrater Reliability..... 86
3.5 STATISTICAL ANALYSIS..... 88
3.5.1 Step One: Create Crime Pairs and Determine Similarity Scores..... 90
3.5.2 Step Two: Assessing Distribution of Data..... 91
3.5.3 Step Three: Predicting Linked Status of Crime Pairs Using Binary Logistic Regression Analysis and Cross Validation of Data..... 92
3.5.4 Step Four: Assessing Predictive Accuracy Using ROC and AUC..... 93
3.5.5 Step Five: Decision Thresholds and Performance Outcomes..... 97
3.6 ETHICAL CONSIDERATIONS 100
3.6.1 Professional Conduct..... 100
3.6.1.1 Multiple Relationships..... 100
3.6.1.2 Personal Impairment..... 100
3.6.2 Confidentiality and Anonymity 101
3.6.3 Legal Implications..... 102
3.7 FUNDING 102

3.8 CHAPTER CONCLUSION 102

CHAPTER 4

RESULTS

4.1 CHAPTER PREVIEW 104

4.2 DESCRIPTIVE STATISTICS 104

4.2.1 Target Selection Behavioural Domain 104

4.2.2 Sexual Behavioural Domain 107

4.2.3 Violence and Control Behavioural Domain 111

4.2.4 Crime Scene Characteristics Behavioural Domain 114

4.3 STATISTICAL ANALYSIS RESULTS 117

4.3.1 Determining Behavioural Similarity: Jaccard's Coefficient 117

4.3.2 Predicting Linked Status of Crime Pairs: Logistic Regression and LOOCV .. 120

4.3.3 Accuracy of Linked Predictions: ROC Analysis and AUC Values 120

4.3.3.1 Discrimination Accuracy for All MO Behaviours 120

4.3.3.2 Discrimination Accuracy per Functional Behavioural Domain 125

4.4 Decision Thresholds 127

4.4.1 Lenient Threshold 128

4.4.2 Mid-range Threshold 128

4.4.3 Strict Threshold 130

4.4.4 Very Strict Threshold 130

4.5 CHAPTER CONCLUSION 131

CHAPTER 5

DISCUSSION

5.1 CHAPTER PREVIEW 132

5.2 OVERVIEW OF KEY FINDINGS 132

5.3 INTERPRETATION OF FINDINGS 134

5.3.1 Overall Behaviour Consistency and Distinctiveness of Serial Murder Offenders in South Africa 134

5.3.1.1 Comparison of Behaviour Consistency and Distinctiveness Between Solved and Unsolved Murder Series 136

5.3.2 Functional Behavioural Domain Effectiveness at Linking Crimes 138

5.3.2.1 Consistency and Distinctiveness of Target Selection Behaviours 140
5.3.2.2 Consistency and Distinctiveness of Sexual Behaviours 146
5.3.2.3 Consistency and Distinctiveness of Violence and Control Behaviours 152
5.3.2.4 Consistency and Distinctiveness of Crime Scene Characteristics 156

5.4 IMPLICATIONS AND USEFULLNESS OF THE STUDY 160

5.4.1 Theoretical Implications 160

5.4.2 Practical Implications 161

5.4.2.1 Investigative Phase 162
5.4.2.2 Trial Phase 165

5.5 CHAPTER CONCLUSION 167

CHAPTER 6

CONCLUSION

6.1 CHAPTER PREVIEW 169

6.2 PURPOSE OF THE STUDY REVISITED 169

6.2.1 Behaviour Consistency and Distinctiveness 170

6.2.2 Solved versus Unsolved 171

6.2.3 Functional Behavioural Domain Effectiveness 171

6.3 LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH 172

6.4 VALUE OF THE STUDY 176

6.5 CHAPTER CONCLUSION 178

REFERENCES

REFERENCES 179

APPENDICES

Appendix A: Turnit-in Plagiarism Report 207

Appendix B: WITS HREC (Non-Medical) Certificate 208

Appendix C: SAPS Permission to Conduct Research 209

Appendix D: Behavioural Checklist (per domain) 210

LIST OF FIGURES

Figure 2.1 Accuracy of crime linkage studies examined by Bennell et al. (2014) according to AUC value Interpretation. 64

Figure 3.1 Adaption of "the Bennell approach to behavioural consistency, distinctiveness, and discrimination accuracy" (Tonkin, 2015, p.114). 79

Figure 4.1 Total number of victims per gender and race categories in solved and unsolved series. 105

Figure 4.2 Total number of victims per age category in solved and unsolved series. 106

Figure 4.3 Number of victims and survival outcome per solved and unsolved series. 106

Figure 4.4 Boxplots of linked and unlinked crime pairs Jaccard's coefficients per..... 118

Figure 4.5 ROC and PRC for all data: AUC .87 ($p < .001$, SE = 0.1, 95% CI = .85 - .88). 122

Figure 4.6 ROC and PRC for all solved data AUC .86 ($p < .001$, SE = .01, 95% CI = .85 - .88). 123

Figure 4.7 ROC and PRC for all unsolved data AUC .88 ($p < .001$, SE = .02, 95% CI = .84 - .91)..... 124

Figure 4.8 Comparison of Full ROC curves between All Data, All target selection variables, and all crime scene characteristics. 127

LIST OF TABLES

Table 2.1 Summary of Methodologies Used by Researchers to Test Crime Linkage 63

Table 3.1 Summary of Cases Used in the Study. 81

Table 3.2 Summary of Datasets and Sub-datasets Subjected to Statistical Analysis. 89

Table 3.3 Summary of Formulas Used to Calculate Performance Metrics. 99

Table 4.1 Target Selection Domain Comparison between Solved and Unsolved Murder Series. 108

Table 4.2 Comparison of Sexual Behaviours between Solved and Unsolved Murder Series. 110

Table 4.3 Comparison of Violence and Control Behaviours between Solved and Unsolved Series. 113

Table 4.4 Crime Scene Characteristics Behavioural Domain Comparison between Solved and Unsolved Murder Series. 115

Table 4.5 Statistical Comparison of Jaccard's Coefficient Between Linked and Unlinked Crime Pairs. 119

Table 4.6 Results of Logistic Regression per Data Set. 121

Table 4.7 Results of ROC AUC for All Datasets. 125

Table 4.8 Summary of AUC Values for Functional Domain Datasets. 126

Table 4.9 Contingency Table of Decision Outcomes Across Thresholds. 129

NOMENCLATURE

AUC	Area Under the Curve
BAU	Behavioral Analysis Unit
COD	Cause of Death
CR	Correct Rejections
DE	Diagnostic Effectiveness
DNA	Deoxyribonucleic Acid
EDR	Emotionally Demanding Research
FBI	Federal Bureau of Investigation
FN	False Negative
FP	False Positive
IPS	Investigative Psychology Section
LOOCV	Leave-One-Out Cross-Validation
LR –	Likelihood Ratio negative
LR +	Likelihood Ratio positive
MO	Modus Operandi
MR	Misclassification Rate
NPV	Negative Predictive Value
pFA	Probability of False Alarms
pH	Probability of Hits
PPV	Positive Predictive Value
PRC	Precision Recall Curve
ROC	Receiver Operating Characteristic
SA	South Africa
SAPS	South African Police Service
TN	True Negative
TP	True Positive
UK	United Kingdom
USA	United States of America
ViCLAS	The Violent Crime Linkage Analysis System

CHAPTER 1: INTRODUCTION

1.1 CHAPTER PREVIEW

This chapter introduces the study by providing an overview of the research and a general orientation to the content and structure of the chapters that follow. It begins by describing and presenting the underlying principles of crime linkage through the examination of crime scene behaviours, while addressing the limitations and criticisms of previous crime linkage research. Thereafter, the research problem is introduced followed by the aims and objectives of the study and potential significance and impact on crime linkage research understanding of serial murder. The chapter concludes with an outline of the subsequent chapters, by providing a structural framework for the research study.

1.2 RESEARCH CONTEXT AND BACKGROUND TO THE STUDY

South Africa has one of the highest number of serial murderers recorded per country in the world (Aamodt *et al*., 2023). As a result of the high cost to life, as well as state resources, apprehension and early detection of serial murder offenders is crucial to prevent further possible victimisation (Pakkanen *et al*., 2021; Woodhams & Davies, 2021; Yaksic, 2024). Although the most reliable form of connecting crimes to the same offender is through scientific forensic evidence such as Deoxyribonucleic Acid (DNA), ballistic evidence, fingerprints, and digital evidence (Grubin *et al*., 2001), Davies and Woodhams (2019) state that the process is expensive, time consuming, and sometimes such evidence is even absent from the crime scene. For example, forensic evidence such as DNA may be unavailable due to possible forensic awareness of the offender, degradation of evidence at the crime scene, and/or a result of poor police work (Labuschagne, 2012; Salfati, 2019; Salfati *et al*., 2015b; Sorochinski & Salfati, 2010; Yaksic, 2024). As a result, investigators need alternative methods which are valid and reliable to assist them in linking and connecting crimes (Woodhams *et al*., 2019).

Crime linkage, a form of behavioural analysis, is the practice of identifying and connecting seemingly unrelated crimes to the same unknown offender based on crime scene behaviours (Bennell & Canter, 2002; Canter, 1995; Woodhams & Bennell, 2015a; Woodhams *et al*., 2007). Research has demonstrated that serial offenders can be linked to crimes based on crime scene behaviours that are similar, yet unique at each crime scene, which form the

underlying principles of crime linkage (Canter, 2000; Horning *et al*., 2015; Knoll *et al*., 2009; Pakkanen *et al*., 2021; Ressler *et al*., 1995; Salfati *et al*., 2015a; Salfati & Bateman, 2005; Santtila *et al*., 2008; Skott *et al*., 2021). These crime scene behaviours exhibit consistency across crime scenes, establishing a similar pattern in behaviour. However, these crime scene behavioural patterns are unique and distinct to the offender, differentiating them from other offenders who commit similar types of crimes (Bennell & Canter, 2002; Woodhams *et al*., 2019).

The purpose of crime linkage is to identify patterns and possible connections between crimes based on behavioural evidence which may not be readily apparent, to assist law enforcement such as investigators, to effectively allocate resources, and obtain specific or more useful information which may have been previously overlooked or unidentified (Bennell & Canter, 2002; Davies & Woodhams, 2019). By linking offenders based on their crime scene behaviours, investigators can connect crimes for the purpose of investigation, prosecution, and conviction (Labuschagne, 2015b). As a result, linking crimes based on behavioural evidence is advantageous as it is proactive in nature, more cost effective, and immediately available once the crime is discovered (Davies & Woodhams, 2019; Labuschagne, 2015a). Crime linkage has become a valuable investigative tool in police investigations and court proceedings by providing similar fact evidence, especially when forensic evidence is lacking (Davies & Woodhams, 2019; Ewanation *et al*., 2023; Labuschagne, 2015a). Similar fact evidence is a legal rule of evidence concerning the admission of prior misconduct of an accused in court, admissible when the unique patterns between the prior acts and the present or current charge, demonstrate a strong logical connection (Acorn, 1991).

Due to the serious implications and consequences of incorrectly linking crimes based on behavioural evidence, it is imperative that crime linkage be thoroughly researched (Brooks & Greenberg, 2021; Sorochinski, 2024). This includes establishing that the underlying principles and methodologies have been tested in the most valid and reliable way. As a result, quantitative methods have been used to determine the accuracy of crime linkage by determining the similarity and distinctiveness of crime pairs (Bennell *et al*., 2023). In particular, Jaccard's similarity coefficient has been a common method used to quantify the level of behavioural similarity between crime pairs (Bennell & Canter, 2002; Pakkanen *et al*., 2021; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). Jaccard's similarity coefficients with outcomes closer to one (1) indicate perfect similarity, and outcomes closer

to zero (0) indicate no similarity in crime scene behaviours between crime pairs (Bennell & Canter, 2002). In addition, logistic regression analysis is the preferred and most common method used to predict linked status, and Receiver Operator Characteristic (ROC) graphs to determine the accuracy of models as indicated by the Area Under the Curve (AUC) in predicting crime pairs by distinguishing between 'linked' (crimes committed by the same offender) and 'unlinked' (crimes committed by different offenders) crime pairs across various thresholds (Bennell *et al*., 2021). As a result, it is important that the impact, and the application of different threshold levels on error rates in practical applications, are provided (Ewanation *et al*., 2023; Woodhams *et al*., 2019).

1.3 RESEARCH PROBLEM STATEMENT

While the principles underlying crime linkage have been tested empirically using several crime types such as serial sexual offences, burglary, theft, and robbery (Bennell *et al*., 2014; Fox & Farrington, 2018), few studies have tested the underlying principles of crime linkage among serial murderers (Melnyk *et al*., 2011; Pakkanen *et al*., 2021). Consequently, the generalisability of the principles of crime linkage across crimes, is questionable. In addition, there has also been variability in the data which suggest that not all offenders maintain consistency in their crime scene behaviours (Bennell *et al*., 2021; Woodhams & Labuschagne, 2012a). For example, contextual and situational factors such as how a victim reacts or resist(s), or whether someone interrupts the offender during the criminal act, can impact on an offender's behaviour pattern (Salfati, 2019; Sorochinski & Salfati, 2010; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). As a result, behaviours considered within the control of the offender display more consistency across crimes (Salfati *et al*., 2015a). As an offender gains confidence and experience in committing crimes, they adapt and ascertain what works and what does not work in order for them to be able to effectively carry out their crimes, and escape detection (Hazelwood & Warren, 2003; Woodhams *et al*., 2007). This is also commonly referred to as *modus operandi* (MO) (Hazelwood & Warren, 2003). However, an offender's MO can also evolve or destabilise and change over time (Turvey & Freeman, 2012a). This highlights the complexity and nuanced nature of offender's behaviour/s, and the challenge in establishing reliable links between crimes (Salfati, 2019; Tonkin *et al*., 2012b; Woodhams & Labuschagne, 2012a).

Furthermore, much of the criticism and limitations of previous crime linkage studies are related to the samples which have been used as they are arguably not representative of what occurs in practice and, therefore, lack ecological validity (Pakkanen *et al*., 2021; Woodhams and Labuschagne, 2012a). Ecological validity refers to the application and generalisability of theory and research to real-world contexts (Schmuckler, 2001). For example, a criticism and limitation is that the majority of crime linkage research studies have only utilised solved crime series (Pakkanen *et al*., 2021; Woodhams *et al*., 2019). It has been suggested that these series were more consistent and similar in nature, and, therefore, easier to link to an offender, and hence were solved (Bennell & Jones, 2005; Burrell *et al*., 2024; Woodhams & Labuschagne, 2012a). This is viewed as a limitation, as investigators are typically investigating unsolved crime scenes with an unknown perpetrator (Tonkin *et al*., 2012b). Therefore, due to the dissimilarity in crime scene behaviours, they are not connected and go unsolved (Bennell & Jones, 2005). This demonstrates the importance of testing the underlying principles of crime linkage using ecologically valid samples (Davidson & Petherick, 2021; Pakkanen *et al*., 2021; Woodhams *et al*., 2019). To the researcher's knowledge, no crime linkage research has been conducted using unsolved murder series.

There is a need to address this gap by testing the underlying principles of crime linkage on a sample of serial murder cases in South Africa which included solved and unsolved murder series. By examining behaviour similarity and distinctiveness of serial murder offenders' behaviour using original police case files, and using samples of solved and unsolved murder series, enhances the ecological validity of the findings of the study and findings of crime linkage research (Pakkanen *et al*., 2021). In addition, due to variability among offending behaviour, the study assesses whether certain functional behavioural domains were more effective at linking crimes, or whether a combination of all MO crime scene behaviours is more useful for linking purposes during the investigative phase. There is an opportunity for research to further provide performance metrics as well as a range of different thresholds, to determine error rates which are necessary and useful for the trial phase, such as in legal proceedings (Ewanation *et al*., 2023).

1.4 PRIMARY AIM AND OBJECTIVES OF THE RESEARCH

The primary aim of the research study is to determine whether behaviour consistency and distinctiveness exists among a sample of serial murder offenders in South Africa based on

crime scene behaviours. However, the outcome was two-fold as through achieving the primary aim of the study, the underlying principles of crime linkage were also tested using unsolved murder series, enhancing ecological validity of crime linkage research. In addition, the study utilised a pragmatic functional behavioural domain approach to determine whether target selection, sexual behaviours, violence and control behaviours, or crime scene characteristics are more useful at linking crimes, or whether a combination of all crime scene behaviours are more effective for linking purposes.

As a result, the objectives of the study are the following:

- To compare the descriptive statistics of behavioural variables between solved and unsolved murder series samples.
- To determine whether behavioural consistency and distinctiveness exists among a sample of South African serial murder offenders by assessing similarity and distinctiveness of all crime scene behaviours using quantitative methods.
- To compare the behaviour similarity and distinctiveness of offenders between solved and unsolved murder series using all crime scene behaviours.
- To identify whether functional behavioural domains or whether including all MO crime scene behaviours are more effective at linking crimes, by comparing behaviour similarity and distinctiveness of each domain.
- To compare the functional behavioural domains between solved and unsolved murder series.
- To apply a range of decision thresholds to determine performance outcomes and error rates which can be useful and applicable for the investigative and trial phases.
- To compare and contrast performance outcomes and error rates between solved and unsolved cases.

By achieving these objectives, the study sought to answer the following research questions:

- Do serial murder offenders in South Africa display consistent yet distinct crime scene behaviours?
- How do solved and unsolved murder series compare with regard to behaviour consistency and distinctives when all crime scene behaviours are considered?
- Are certain functional behavioural domains more useful at connecting crimes, or are all crime scene behaviours more effective for linking purposes?

- How do solved and unsolved crimes compare within these domains?
- What are the practical implications of various decision thresholds and how are they beneficial during the investigative and trial phase?
- What are the error rates and how do these decision thresholds compare between solved and unsolved cases?

1.5 SCOPE OF THE STUDY

This research adopts a positivist approach to investigate and explore the behaviour consistency and distinctiveness among serial murder offenders in South Africa. As a result, the scope of the study is limited to exploring and examining the underlying principles of crime linkage through quantitative analysis. The purpose of the study is not to identify, infer, or speculate on the psychological profile or personality characteristics of offenders, nor to determine the reason or possible causation for the offender to become a serial murder offender. In addition, the specific outcomes such as frequency of variables will not be explored to determine trends or themes, as the sample is limited. Therefore, frequency outcomes of the specific behavioural checklist variables used in this study should not be generalised to all serial murder offenders in South Africa, nor to other countries. Additionally, aspects such as a cost-benefit analysis at determining the cost of linking a crime or not linking a crime, is outside the scope of the study. Lastly, due to the sensitivity and confidential nature of the study, the researcher will not expound upon specific cases or details regarding the crime scenes, and only aggregated data is reported on.

1.6 SIGNIFICANCE OF THE STUDY

This is the first known research study to date globally to include unsolved murder series in testing the principles of crime linkage among serial murder cases. The inclusion of unsolved murder series as well as using original police case files, will enhance the ecological validity of crime linkage research, which will be a significant contribution to the field of investigative psychology and crime linkage (Ewanation *et al*., 2023; Pakkanen *et al*., 2021; Woodhams *et al*., 2019). By testing the underlying principles of crime linkage using a sample which reflects practical investigative challenges, this study provides a more accurate assessment of the effectiveness of linking crimes using behavioural evidence. This is the first study to use the *gold standard* methodology of crime linkage research in the analysis of serial murder cases in South Africa as well as the Global South. It achieved this by using Jaccard's

coefficient to determine similarity of crime pairs; binary logistic regression analysis to predict the linked status of crime pairs; Leave-One-Out Cross-Validation (LOOCV) method to cross validate the results, and ROC and AUC to assess the accuracy of the predictions (Bennell *et al*., 2014; Burrell *et al*., 2024; Tonkin *et al*., 2012b; Woodhams *et al*., 2019). In addition, by examining and comparing offenders' behaviour within functional behavioural domains (such as target selection behaviours, sexual behaviours, crime scene dynamic behaviours, and violence and control behaviours), this research explores serial murder offenders' behaviour consistency and distinctiveness within these behavioural domains to determine the effectiveness of each behavioural domain at linking crime pairs.

In addition, through examining the behaviour distinctiveness and consistency of serial murder offenders in South Africa using crime scene behaviours, this study further contributes to crime linkage research by providing a uniquely South African analysis, as crime linkage is an area of research which is predominantly examined in Europe, the United Kingdom (UK), and the United states of America (USA) (Melnyk *et al*., 2011; Pakkanen *et al*., 2021; Tonkin & Woodhams, 2017). Therefore, this study will contribute towards the understanding of validity and reliability of crime linkage as an investigative tool for serial murder offences both internationally as well as in South Africa. The study provides valuable insights that may inform the development of effective investigative strategies, enabling law enforcement to effectively identify, and apprehend serial murder offenders based on behavioural evidence. In the current context of DNA backlogs in the SAPS Forensic Sciences Laboratories (FSL) (Machisa *et al*., 2023; Parliament of South Africa, 2025), it can be argued that the scientific development of crime linkage based on behavioural analysis is becoming both relevant and necessary in serial murder investigations and subsequent prosecutions. DNA might not be present in a case, or due to backlogs there are significant delays in obtaining results, whereas crime scene behaviour is present and immediately available in each case (Davidson & Petherick, 2021; Salfati, 2019).

1.7 DEFINITION OF KEY TERMS

1.7.1 Area Under the Curve

The Area Under the Curve (AUC) is a common system of measurement used in research, such as crime linkage, to determine the relative accuracy of a binary classification logistic regression model (Hanley & McNeil, 1982; Hosmer & Lemeshow, 2000; Swets, 1973). In

this research, the AUC represents the likelihood that a randomly selected linked crime pair will have a higher probability of being linked compared to a randomly selected unlinked crime pair (Bennell & Canter, 2002; Bennell & Jones, 2005).

1.7.2 Correct Rejections

Correct rejections, also referred to as *true negative* (TN), refer to crimes which were predicted to be unlinked and were in fact committed by different offenders (Ewanation *et al*., 2023). In other words, the linked prediction is correctly rejected, as the crime was committed by a different offender (Woodhams *et al*., 2019).

1.7.3 Crime Linkage

Crime linkage, also commonly referred to as crime linkage analysis, case linkage, comparative case analysis, or linkage analysis (Rainbow, 2015), is the forensic practice of identifying crimes which may have been perpetrated by the same offender using behavioural evidence (Bennell & Canter, 2002). The process involves analysing and identifying behavioural patterns exhibited at crime scenes, comparing them to identify similarities across crime scenes, and connecting them based on behavioural information (such as the MO of the offender) (Bennell *et al*., 2015; Tonkin, 2015).

1.7.4 Criminal Profiling

Criminal profiling, often referred to as offender profiling, is the practice of inferring characteristics of an unknown offender based on the analysis of crime scene information (such as crime scene behaviours), in order to assist in investigations (Crabbé *et al*., 2008; Turvey, 2012a).

1.7.5 False Alarms (FA)

False alarms (FA) are also often referred to as *false positives* (FP) or *1-specificity* as plotted on the *x*-axis on the ROC curve (Ewanation *et al*., 2023). False alarms (FA) refer to crimes which are incorrectly identified as linked, as the crime was committed by a different offender (Bennell *et al*., 2015).

1.7.6 Hits (H)

Hits is also referred to as *sensitivity* and *true positive* (TP) which is indicated on the *y*-axis of the ROC curve (Bennell & Canter, 2002). Hits (H) occur when a crime is predicted to be linked, and this prediction is accurate as the crimes were committed by the same offender (Woodhams *et al*., 2019).

1.7.7 Jaccard's Coefficient

Jaccard's coefficient is a similarity index which measures the level of similarity and/or dissimilarity of two variables (Bennell & Canter, 2002). In crime linkage research, it is used to determine the degree of similarity of crime pairs based on behaviours displayed at crime scenes. The range is from zero (0) which indicates no similarity, to one (1) which indicates complete or perfect similarity (Bennell & Canter, 2002).

1.7.8 Linked Status

The linked status or linkage status refers to whether a pair of crimes are considered to be linked, when a crime has been committed by the same offender, or unlinked, when the crime has been committed by different offenders (Ellingwood *et al*., 2013; Woodhams *et al*., 2007).

1.7.9 Misses

Misses (M), also referred to as *false negatives* (FN), refer to a model incorrectly classifying a crime pair as unlinked, when in fact the crime pair was committed by the same offender (Bennell & Canter, 2002). In other words, the model missed an opportunity to correctly link a crime pair committed by the same offender (Woodhams *et al*., 2007).

1.7.10 Murder Series

A murder series, often referred to as serial murder, homicide series, serial homicide, or the sensationalised term *serial killings* in other countries, is a set of related murders (unlawful killing) as they are acts committed by the same offender (Holmes & Holmes, 1998). The study uses the Federal Bureau of Investigation (FBI) and the South African Police Service (SAPS) definition of serial murder which is: at least two murders committed on two separate occasions by the same offender(s) (Labuschagne & Salfati, 2015; Morton & Hilts, 2008).

1.7.11 Receiver Operating Characteristic

The Receiver Operating Characteristic (ROC) is a statistical analysis used to evaluate the overall discrimination accuracy of a binary classification model (Swets, 1988). The output curve illustrates the diagnostic ability of a binary classification system at various threshold settings, as the curve plots the true linkage status against the false positive rate (Bennell & Canter, 2002).

1.7.12 Threshold

A threshold is the value, or point, at which a decision is made to classify a crime pair as either linked or unlinked, based on the model's predicted probability output value (Bennell *et al*., 2007). A strict threshold implies that the number of false alarms is minimised, whereas a lenient threshold suggests that the number of hits are maximised (which often corresponds with a high false alarm rate) (Ewanation *et al*., 2023).

1.8 OUTLINE OF THE STUDY

Following the conventional monograph 'block' format, this research study is presented over six chapters and uses the Harvard referencing style as stipulated and required by the University of Witwatersrand (WITS) Faculty of Health Sciences style guidelines for a Doctoral thesis. The first and current chapter introduces the context of the research, providing a brief overview of the field of crime linkage before outlining the primary aim, objectives, and significance of the research study. The second chapter explores the current understanding of serial murder, demonstrating the complexity in defining serial murder, and how offender profiling and particularly crime linkage are valuable research and investigative tools in the investigation process and apprehension of serial offenders by linking crime thorough behavioural evidence. The existing theory underpinning crime linkage is presented, namely the behaviour consistency and distinctiveness of offenders, as well as the methodologies used, and empirical studies which have tested these two assumptions. Limitations of existing research is presented such as the generalisability and ecological validity of studies which have assessed and tested the principles underlying crime linkage.

The third chapter presents the methodology used in the study to achieve the research aims and objectives of the crime linkage approach and statistical analysis used to assess and determine behaviour similarity and distinctiveness. Issues of validity and ecological validity

are addressed, as well as the ways the researcher chose to reduce/limit them. Chapter four presents the main findings and results of the study, first by presenting the descriptive statistics, followed by the results of the statistical analysis, and contingency tables which demonstrate the outcomes of a range of decision thresholds used. Following the results chapter, the fifth chapter presents a discussion of the findings of the research study, highlighting the insights gained through a detailed analysis of the results. Lastly, chapter six concludes the study by summarising the main findings and value of the research, before addressing limitations of the study, and providing recommendations and opportunities for future research.

1.9 CHAPTER CONCLUSION

This chapter presented an introduction and context for the research study. The underlying principles of crime linkage were introduced, and how these core assumptions are particularly relevant and applicable to the study of serial offenders. The chapter provided an overview and outlined the development of crime linkage research as well as limitations of previous crime linkage research studies, and how the researcher aims to address these limitations. The significance of the research study as well as the scope of the study were presented. The chapter concluded by presenting the outline of the study, and the approach used by the researcher to address the research objectives. The following chapter will explore serial murder and crime linkage.

CHAPTER 2: LITERATURE REVIEW

2.1 CHAPTER PREVIEW

This chapter provides a comprehensive review of the literature on serial murder, highlighting the lack of consensus regarding the definition of serial murder, and what constitutes a murder series. The researcher provides the different definitions available, including the one chosen for this study and the reasons behind its choice. Although the underlying psychological motivations and psychological profile of the offender are not the primary aim or subject of the study, a brief background on the research of serial murder and offender profiling, which include psychological motivations and psychological profiles of murder series, is important to consider for the development of certain crime scene behaviour/s which have been identified as useful for linking serial murder cases. How crime scene behaviours link the same individual to multiple crimes is explored through crime linkage, before the implications and limitations of the practice of crime linkage is discussed. Lastly, the gap in literature is identified and the primary aims of the study is presented.

2.2 SERIAL MURDER: A MORBID CURIOSITY

Serial offenders have a cost to human life as well as state resources, and an impact on the communities where they occur, therefore, it is important to apprehend serial offenders as soon as possible in order to protect society and prevent future victimisation (Woodhams & Davies, 2021a). There has been a growing media and public interest as well as an increase in the volume of research in attempting to understand serial murder offenders and their offending behaviour (Knoll *et al*., 2009). *Morbid curiosity* is a term given to the fascination in subjects and topics which usually involve death, or some form of emotional terror (Harrison & Frederick, 2022). Whether single or multiple victims, there is a natural intrigue and curiosity regarding the psychology of someone who systematically targets and murders another human without apparent motive, a concept which is difficult to understand and comprehend (De Wet & Potgieter, 2015). This morbid curiosity, particularly regarding crimes such as serial murder, has become a popular genre amongst professionals as well as the public, with true-crime and fictional accounts growing in number and popularity in books, television, streaming and film (Harrison & Frederick, 2022; Knoll *et al*., 2009; Yaksic, 2022; Yaksic, 2024). The fascination and intrigue likely stem from the fact that,

according to Kelleher and Kelleher (1998), serial murderers look, act, and sound just as everyone else.

In addition, offenders who have murdered multiple victims are seen as even more distinct and unique, in comparison to offenders who have murdered a single victim (Wright *et al*., 2008). Serial murder is a global phenomenon, and research and studies on serial murder have emanated from the USA (Burgess *et al*., 1986; Douglas *et al*., 1986; Hickey, 2012, 2016; Holmes & Holmes, 2002; Keppel, 2000; Keppel & Birnes, 2018; Keppel & Walter, 1999; Ressler *et al*., 1986, 1995), Europe (Harbort & Mokros, 2001; Pakkanen *et al*., 2021; Santtila *et al*., 2008; Sturup, 2018), the UK (Jenkins, 1991; Flynn *et al*., 2024; Gresswell & Hollin, 1994), Australia (Eichinger & Darjee, 2021; Kocsis *et al*., 2002; McKinley & Petherick, 2021; Mouzos & West, 2007), India (Deepak, 2021), and South Africa (Hodgskiss, 2004; Horning *et al*., 2015; Labuschagne, 2001, 2021; Labuschagne & Salfati, 2015; Salfati *et al*., 2015a, Salfati *et al*., 2015b; Sorochinski *et al*., 2015).

Due to the impact on society and fascination with this type of crime, these research studies have been conducted in order to understand this complex and heterogeneous crime by exploring risk factors, possible aetiology, and causation of serial murder offenders (Allely *et al*., 2014; Singer & Hensley, 2004; Wright & Hensley, 2003; Yang, 2023). In addition, research has explored the underlying motivations, psychological characteristics, and crime scene behaviours of serial murder offenders, in order to assist law enforcement during investigations (Douglas & Munn, 1992; Douglas *et al*., 2013; Ressler *et al*., 1995). Another important aspect is identifying potential risk factors for an individual to develop into a potential serial murder offender which researchers have analysed through the progression of serial murderers' life histories (Keatley *et al*., 2021; Marono *et al*., 2020). Although serial murder is not a new occurrence, there has been increasing curiosity and intrigue which developed steadily from the 1980s when the term *serial killer* was first popularised for describing this type of crime (Keppel, 1995).

2.2.1 Brief History of the Term and Prevalence of Serial Murder

According to Petherick *et al*. (2022), James Brophy was the first person to label this type of offender as a serial murderer and who published the book: *The Meaning of Murder* in the UK in 1966, and 1967 in the USA. However, Robert Ressler, a deceased FBI agent who

joined the FBI in 1970, stated that he was the first person to introduce the term *serial killer* (Ressler & Shachtman, 1992) after conducting the first study on serial murder in the USA (Ressler *et al*., 1986). Regardless of who developed the term, Ressler and colleagues brought attention to this type of multiple victim murderer through the publication of literature such as the *Crime Classification Manual*, which was first published in 1992 (Douglas *et al*., 1992; 2013), and *Sexual Homicides: Patterns and Motives* (Ressler *et al*., 1995). Researchers, professionals, and the public alike, are fascinated by how an individual may deliberately harm another person, without apparent reason or provocation, deriving pleasure, and satisfaction from the act, or multiple acts, while still appearing 'normal' and functional to the outside world (Davies & Woodhams, 2019). Although serial murder typically has low occurrence rates, especially in comparison to other crime types (Yaksic, 2023), it has a significant impact on society and the communities which they directly impact (Davies & Woodhams, 2019).

While the term may only have been coined in the latter half of the 1900s, serial murder itself is not a new or recent development (Morton & Hilts, 2008) nor a crime type which is limited to certain countries. Haggerty (2009), Hodgskiss (2004), and Wilson (2004) suggest that there was a global increase in serial murder and violent crime during the 1980s and 1990s, as a result of societal and cultural influences. It has been suggested that the rise and peak in the number of serial murder cases during the 1980s and the 1990s was a result of media attention and the sensationalising of serial murder offenders (Haggerty & Ellerbrok, 2011; Haggerty, 2009; Wilson & Seaman, 2007; Wilson, 2004).

Despite the interest in serial murder, it is still an uncommon type of crime with a prevalence of between 1 and 2% of all murder estimates in countries such as the US and Europe (Knoll *et al*., 2009; Morton & Hilts, 2008; Pakkanen *et al*., 2021; Sturup, 2018). Interestingly, as the growing interest and fascination in serial murder peaked between the 1970s and 1990s, there has reportedly been a global decline in the number of murder series since then (Yaksic, 2023). The reported decline could be attributed to the early apprehension of individuals, who may have escalated into becoming a serial murder offender, given the opportunity. This could largely be due to advances in forensic sciences and investigation by law enforcement such as increased surveillance, advanced technology, as well as advances in scientific methods such as through DNA, which have all contributed to the decline in this specific occurrence (Yaksic, 2023).

Interestingly, McKinley and Petherick (2021) suggest that the increase in technology and greater acceptance of sex work has enabled individuals to gain online access to material which satisfies deviant fantasies and desires, and/or to connect individuals who share similar fantasies in order to act out and appease devious sexual fantasies, either online or in person. As a result, this could mitigate instances where an individual may abduct a victim to act out certain devious fantasies, and who commits murder to avoid detection (Yaksic, 2023), which Freeman and Turvey (2012) refer to as a *precautionary act.*

Aamodt *et al*. (2023) regularly update one of the largest databases regarding the information pertaining to the number of serial murderers per country, which is referred to as the *Serial Killer Information Centre* which is research based at Radford University. According to the latest report from Aamodt *et al*. (2023), South Africa most recently ranked sixth in the world with regard to the number of serial murderers per country, after the USA, UK, Russia, Japan, and India. However, it can be argued that these statistics may not be reliable or a true representation, as a result of a lack of consensus regarding the definition used to define a murder series, and differences in how information is stored by law enforcement, which then pose challenges for cross country comparisons (Aebi, 2010; Buil-Gil *et al*., 2025; Yaksic, 2023). For example, different countries utilise different definitions for serial murder, and South Africa utilises a broad definition which could also suggest the high rate (Hickey, 2006; Hodgskiss, 2004; Labuschagne, 2021). In addition, SAPS is reported to be one of the few law enforcement agencies globally, which accurately keep up-to-date records and report on the serial murder offences occurring within the country, which could also possibly result in the high rate (Labuschagne, 2021).

However, the drop in South Africa's international ranking from fourth in 2020 (Aamodt *et al*., 2020), may also be impacted by the fact that the last updated records done by the Investigative Psychology Section (IPS) of serial murder in South Africa was done in 2016 (Myburgh, 2023), as well as the inclusion criteria for the *Radford* report. For example, one of the criteria for murder series to be included in the reported statistics is that the identity of the (serial) murderer is known to law enforcement, and that the name of the offender and the number of victims in the series has been made public (Aamodt *et al*., 2023). Therefore, although these statistics are interesting, and perhaps provide an overview of solved murder series, they are limited as they do not reflect what is occurring in natural databases due to excluding (unsolved) series. For example, Labuschagne (2017) reported that there were

approximately 160 murder series in South Africa, yet Aamodt *et al*. (2023) report 129 identified murder series. Furthermore, these statistics are also likely underreported, as some countries may have not made the information public, are not accurately reporting or disclosing their own statistics, and/or as a result of poor record keeping (Aamodt *et al*., 2023; Labuschagne, 2021; Yaksic, 2024).

Although there has been great interest in the study of serial murderers since the 1980s, there is still some confusion regarding what constitutes or defines a serial murderer, and the concept of serial murder has been a subject of extensive debate among researchers, leading to a lack of consensus on its precise definition (Castle & Hensley, 2002; Farrell *et al*., 2013; Heide & Keeney, 1995; Keeney & Heide, 1994). As a result, serial murder, which appears to be a unique type of violent and aggressive crime (Pakkanen *et al*., 2021), continues to attract discussion and debate among those who try to define what represents a murder series (Kelleher & Kelleher, 1998). However, in order to study and determine serial offenders' behaviour using crime linkage, a description and understanding of how academics and practitioners have tried to define serial murder needs to be expanded upon, before the definition used for the purposes of this study is presented.

2.2.2 Definitions of Serial Murder

Serial murder forms one of the subcategories of multiple victim murders (Petherick *et al*., 2022) and is often confused with *spree* and *mass murder* (Fox & Levin, 2014; Meloy & Felthous, 2004; Messori, 2016). Heide and Keeney (1995) describe spree murder as "The killing of three or more victims in different locations but within the context of one event" (p. 301). Mass murder can be defined as a single incident or event, during which there is the intentional murder of three or more victims in the same location (Fox & Levin, 2014; Meloy & Felthous, 2004). The key difference between serial murder, mass, and spree murder, is that in a serial murder, there is a time interval, often referred to as an emotional *cooling off period* between each murder (Haggerty, 2009; Ressler *et al*., 1986; Skrapec, 2001a). In one of the earliest definitions of serial murder proposed by Egger (1984), he suggested a number of characteristics such as: two or more victims are murdered; each murder occurs in separate incidents (such as geographical locations); the victim and offender are not acquainted; victims are usually vulnerable (such as sex workers, or homeless individuals); the offender's main intention and motive for the murders is not in order to steal material items, but to exert

power and dominance over their (often vulnerable) victims. Egger (1984) further stated that victims may have some significance to the offender, and, as a result of this shared symbolic meaning, they may often share similar characteristics. In other words, there may be consistency in the 'type' of victim that the serial murder offender chooses to target (Egger, 1984).

Similarly, Holmes and De Burger (1985) stipulated repetitive one-on-one stranger murders, which are intrinsically motivated, as they are not motivated by external reasons such as by economic or material factors. Heide and Keeney (1995) further excluded murders which were politically motivated, or which were part of military activities. However, Heide and Keeney (1995) defined serial murder as having three or more victims murdered in separate incidents over an extended period, with the murder activity chosen by the offender, and which occurs in civilian contexts. The National Institute of Justice (NIJ) defined serial murder as, "A series of two or more murders, committed as separate events, usually, but not always, by one offender acting alone" (Newton, 2000 p. 205). Skrapec (2001a) defined serial murder as, "Three or more murders committed by the same person over a period of time where the primary motivation of the offender is personal gratification" (p. 22).

In 2005, due to the difference in opinion and understanding on what defines a serial murderer, the FBI held an international symposium in order to reach consensus and understanding amongst the delegates which included various international law enforcement agencies, researchers, clinicians and academics (Labuschagne, 2021). The FBI Behavioral Analysis Unit (BAU) defines serial murder as, "The unlawful killing of two or more victims by the same offender(s) in separate events" (Morton & Hilts, 2008, p. 9). Other researchers, such as LaBrode (2007), further suggest that a serial murderer must murder at least two victims, and there must be a cooling off period between the murders. He also postulates that the victims are usually strangers to the offender, and that the murders are unrelated. Canter (2010) broadly described serial murder as multiple murders committed by the same individual with a *cooling off period* between the crimes. Dr Micki Pistorius (2018) a South African counselling psychologist who worked as a profiler for the SAPS for six years, and who started the Investigative Psychology Unit (IPU) in 1997 (later restructured and expanded to the IPS in 2011), provided the following definition for serial murder:

> A serial killer is a person or persons who murders several victims, usually strangers, at different times and not necessarily at the same location, with a cooling-off period in between. The motive is intrinsic; an irresistible compulsion, fuelled by fantasy which may lead to torture and/or sexual abuse, mutilation and necrophilia (Pistorius, 2018 p. 75)

Most recently, Petherick *et al*. (2022) proposed a definition which includes the following four criteria: two or more murders committed by the same offender; the offences have been linked reliably; the murders are separate offences and there is a period of no offending between each murder; the motives for these murders are for personal gratification, and not corporate, institutional, or organisational in nature (Petherick *et al*., 2022).

However, while several definitions of serial murder have been proposed, each has its own set of criteria and limitations. Despite these efforts, defining serial murder remains challenging due to several factors. One of the challenges encountered is the victim count, which varies across definitions. Additionally, the requirement for victims to be strangers and the inclusion of a cooling-off period further complicates the definition (Yaksic, 2023). Labuschagne (2021) notably points out that *criteria* and *characteristics* are often confused when it comes to defining serial murder. He states that this is a limitation as, for example, a characteristic is that serial murder offenders are *usually* male, they *typically* target strangers and are *often* sexually motivated (Labuschagne, 2021). These definitions are often describing characteristics of common features, and not criteria for defining a murder series (Labuschagne, 2021). When these characteristics (usually prefaced by words like ‘often and ‘typically’) are elevated to criteria status the definition becomes vague or limited in use (Labuschagne, 2021). However, as seen from the definitions provided above, most of the definitions include number of victims, motivation of the offender, and time interval between murders, and linkage (Petherick *et al*., 2022). Before presenting the definition used in this study, each of these aspects will be explored further below, highlighting various limitations and shortcomings of existing definitions which can limit the application of the definition.

2.2.3 Criticism and Limitations of Definitions

2.2.3.1 Victim Count

One of the most discussed criteria amongst the differing opinions in the definition of serial murder offenders is related to the victim count as it is seen as one of the defining characteristics of serial murder (Fridel & Fox, 2018; Holmes & Holmes, 2013; Labuschagne, 2021). While the symposium facilitated by the FBI reached general consensus of specifying two or more victims in 2005, Fridel and Fox (2018) suggest that the victim count criterion should revert back to a minimum of three or more murdered victims to meet the criteria of a murder series. They argue that by only including two victims in the definition this distorts and conflates the population of serial murder offenders (Fridel & Fox, 2018). Furthermore, they argue that there is a difference between serial murder offenders who murder three-to-seven victims, and those that murder eight victims and above, as they reportedly differ with regard to severity, motive, use of torture, and presence of a co-offender (Fridel & Fox, 2018). Labuschagne (2021) disagrees and counters this argument by stating that all murder series started out with two-victims, however, there was a *progression* to a three-victim, and eight-victim murder series.

Chai *et al*. (2024) suggest that the prolificity of a serial murder offender is not just impacted by the victim count, but the rate at which the offender commits the murders, as this is likely going to be a strong indication of the criminal intensity of the offender. Petherick *et al*. (2021) hold a similar perspective to Labuschagne (2021) as they agree that definitions which include a threshold of three or more victims would be counterproductive as, "Such a threshold ignores a critical feature of the serial offender: the crimes are prone to repetition" (p. 12). Labuschagne (2021) also suggests that most individuals do not ever commit one murder, let alone two therefore, if someone has committed *two* murders, that is already a small, yet very distinct group of individuals.

Yaksic *et al*. (2021) further suggests that specifying a victim count to more than one victim may even be problematic, as an offender may not have had an opportunity to commit more murders as a result of early apprehension, and, therefore, their murder series could not progress further due a lack of opportunity to do so. Vincent *et al*. (2024) agree with Yaksic *et al*. (2021) and suggest that there should be a classification for murderers who murder two victims to be classified as *potential* serial murderers as they argue that the two-victim count was for law enforcement purposes and not for researchers. Therefore, it would be difficult to infer than an individual should only be classified as a serial murder offender if they have three or more victims (Yaksic, 2018, 2023), as Adjorlolo and Chan (2014) suggest that the

intention of the offender should be more important to consider than the actual victim count. Put differently, some offenders may have intended to murder more victims yet were caught by law enforcement before they were able to continue with their murder series (Labuschagne, 2021; Petherick *et al*., 2022; Williams, 2023). In addition, specifying a higher victim count could result in a delay of the activation of specialised police resources, such as the implementation of a task force, and consultation with experts in the field of serial murder (Labuschagne, 2021; Petherick *et al*., 2022).

2.2.3.2 Cooling off Period

Turvey (2012b) described the cooling off period as, "the interval during which the offenders psychologically disconnect, separate, or compartmentalise themselves from the behaviours and motives that led to, or culminated in, homicidal behaviour and then reintegrate back into their non-criminal lives and activities" (p. 543). Turvey (2012b) further argues that there is no way of predicting whether the offender may seek out another victim the following day, or whether there will be an extended period of dormancy. Therefore, this emotional cooling-off period varies and can range from a day, week, month, or even years (Burgess, 2006; Sutton & Keatley, 2021). In South Africa, one serial murder offender is known to have committed three murders over a period of 21 years with 17 years between the first and second murder, and four years between his second and third murder (Labuschagne, 2021).

Sorochinski and Salfati (2010) suggest that the time range or interval between crime series should be explored further. They suggest that there may be changes in an offender's behaviour during the cooling off period due to learning and development such as through incarceration, the media, or through individual changes in temporary context of the offender's life (Sorochinski & Salfati, 2010). Due to the difficulty in quantifying a cooling off period, some researchers suggest that spree and serial murder are the same phenomenon, and difficult to classify separately (Osborne & Salfati, 2015; Yaksic *et al*., 2021). Petherick *et al*. (2022) succinctly summarises the above by stating: "the non-offending period may not be dictated by a cooling-off from the offending itself, but rather an enforced period of dormancy by factors outside of their control" (p. 15). Petherick *et al*. (2022) posit that what the time period between each murder *means* to the offender, is more important than the duration of time itself. Therefore, although there does appear to be consensus that there is a time interval or separation of time between murders in order to differentiate them, including

a cooling off period in an operational definition is problematic, as it is a subjective process for each offender, difficult to quantify, and can only be ascertained after speaking with the offender (Petherick *et al*., 2022).

2.2.3.3 Motive

Researchers and practitioners often refer to the intrinsic motivation of the offender when defining serial murder (Adjorlolo & Chan, 2014; Egger, 1984; Mouzos & West, 2007; Petherick *et al*., 2022; Pistorius, 2018; Skrapec, 2001b). This is because victims of serial murder offenders are often strangers to them (Chan *et al*., 2015; Haggerty, 2009; Pakkanen *et al*., 2015b; Ressler *et al*., 1995). As a result, serial murder is referred to as a psychologically motivated crime, as there seems to be an intrinsic motivation to commit these types of crimes (Hazelwood & Warren, 2003). In other words, there is no apparent external motivation to commit the act, other than an inner desire and impulse to do so (Pistorius, 2018). This suggests that the offender is not primarily motivated by external factors such as financial reasons, but by an inner desire and need to do so. For example, in a series of armed robberies where victims are murdered; these murders could be viewed as *precautionary acts* that the offender took to reduce being caught and identified by the victim, but were not the primary motive of the offender, as the primary motive was externally driven in the form of monetary gain (Freeman & Turvey, 2012; Petherick *et al*., 2022).

Although there does seem to be somewhat consensus that serial murder is not primarily or solely focused on external gratification, there is reportedly an over emphasis on the sexual motives of serial murder offenders (Bateman & Salfati, 2007; Harbort & Mokros, 2001; Kraemer *et al*., 2004; Morton & Hilts, 2008). The problem with including motive in the definition of serial murder is that motive, particularly during the initial stages and during the course of investigations, is not always evident or immediately apparent (Petherick *et al*., 2022). Turvey (2012a) also refers to the *principle of unintended consequences*, where the crime scene may not have been found in the way the offender had intended. In addition, Turvey (2012a) suggests that offenders can have multiple motives which can be across crimes, as well as having various motives within one particular crime (Kraemer *et al*., 2004; McKinley & Petherick, 2021; Morton & Hilts, 2008). Freeman and Turvey (2012) refer to this as the *principle of motivational dynamics.* In addition, motivations of the offender can

be influenced and impacted by substance use, the offender's mood, the offender's mental state, and response from the victim (Turvey, 2012a).

A limitation of murder series is that valuable information in determining the possible motive of the offender through the verbal and nonverbal behaviours of the offender which could have been gained from the victim cannot, of course, be ascertained when the victim is deceased. As a result, investigators often rely on crime scene behaviours to infer or hypothesise the motivations of an offender (Freeman & Turvey, 2012). This of course, can be problematic, as the offender may deliberately stage crime scenes by taking items from the scene to disguise their true motive, or display victims in certain positions (often referred to as staging), in order to mislead investigators (Freeman & Turvey, 2012). In addition, it has been found that serial offenders are often more forensically aware before and after their murders in comparison to once-off murder offenders (Chan *et al*., 2015; Pakkanen *et al*., 2015b), and, as a result, may not leave any evidence which suggest or reveal the true motive/s of their crime (Beauregard & Bouchard, 2010; Petherick *et al*., 2022; Petherick & Ferguson, 2009). Furthermore, even if a motive is ascertained, this does not necessarily assist in identifying the offender, and could also delay task teams being activated, due to multiple or different motives across crimes (Labuschagne, 2015b).

2.2.3.4 Victimology/Stranger Victims

Further criticism of Egger (1984), LaBrode (2007), and Pistorius (2018) definitions are the suggestion that serial murder offenders target strangers. As mentioned previously, Labuschagne (2021) states that this is not a criterion for being defined as murder series, but a likely characteristic of serial murderers. While research suggests that serial murderers often target strangers in comparison to once off murders (Chan *et al*., 2015; Pakkanen *et al*., 2015b), not all serial murderers target strangers, or only strangers. For example, in South Africa, there are cases of murder series where the offender and victim have known one another. Previous research on serial murder offenders in South Africa has shown that most serial murderers in South Africa are from rural, and often low-income groups (Labuschagne, 2021). As a result, they often target victims in the area which they are familiar with, and, as a result, may know some of their victims due to small population size in that specific town or area (Labuschagne, 2021). Therefore, including a criterion which states that the victim and offender must be strangers is problematic, particularly within the South African context.

For example, Stewart Wilken was convicted for committing multiple murders and he knew some of the victims. One victim was his own daughter, another victim was an ex-girlfriend's son, but his victimology included stranger sex workers and stranger street children (Labuschagne, 2021).

2.2.3.5 Linked Murders

In order to address the concerns of the cooling off period, victim count, and motive, Petherick *et al*. (2022) proposed two or more *linked* murders in their definition of serial murder. Petherick *et al*. (2022) further expounded upon what they identify and refer to as hard and soft linkage. They referred to *hard linkage* such as forensic evidence such as DNA evidence therefore, the crimes can reliably be determined as linked. Whereas Petherick *et al*. (2022) referred to *soft linkage* as the analysis of the behavioural evidence of the crime scene through examination of the MO, and signature of the offender displayed across crimes (which will be discussed further under the crime linkage section of this chapter).

Despite creating a novel approach to include linkage in the definition of serial murder, identifying who is qualified to determine whether a crime scene is linked through behavioural evidence, may be problematic (Petherick *et al*., 2022). For example, in the South African context, there is no qualification to become a 'profiler' per se, and many investigators and or members of the police service may have vast experience, yet are without formal qualifications (Labuschagne, 2021). Therefore, determining who or what constitutes someone to be able to reliably link crimes through behavioural evidence, may be problematic and needs to be explored further. In addition, it could be argued that the offender is still a serial murderer, even if law enforcement is not aware of the murders or connection between them, let alone being able to reliably link them to the same offender. Nevertheless, Petherick's definition of serial murder appears to be one of the more useful definitions when providing criteria of serial murder.

2.2.4 Definition Used in this Study

Given the above-mentioned challenges, and in order to study serial murder, an operational definition must be utilised. Therefore, this study adopts a definition consistent with the SAPS definition which is the same offender(s) commits two or more murders on separate occasions (Labuschagne 2021). This definition was selected because it is consistent with the definition

utilised by the FBI BAU (Labuschagne & Salfati, 2015), which is the unlawful killing of two or more individuals by the same offender/s in separate incidents (Morton & Hilts, 2008). This definition was also chosen for its inclusive approach to align with the study's objectives. Furthermore, this broad definition of serial murder allows for cases to be included based on the core criteria of murder series, and not excluded if they were based on descriptive characteristics of serial murder offenders, which can be limiting (e.g. "usually target strangers") (Labuschagne, 2021).

Additionally, for the purpose of consistency, and producing valid and reliable research, a broad definition does not limit the sample based on specific criteria which have not reached a formal consensus internationally (Labuschagne, 2021). Despite the complex and multifaceted nature of defining serial murder, with various researchers offering different perspectives, understanding these definitions are valuable for the subsequent analysis of psychologically motivated crimes. Although this study uses a positivist approach and does not attempt to determine why or how people become serial murderers, it is interesting to consider some of the possible underlying psychological motivations and aspects of murder in general. Exploring the underlying psychology of serial murder offenders can assist in understanding the psychology informing certain behaviours which result in consistent yet unique crime scene actions, which are necessary for determining crime linkage (Woodhams & Toye, 2007). The following section will present some of the most common typologies and classification systems of serial murder and murder typologies before examining serial murder within the South African context.

2.2.5 Serial Murder Classification Systems

Psychologically motivated crimes are usually not motivated by external factors, such as financial motives, but by a primary motive to commit the crime for reasons such as control, thrill, or enjoyment (Labuschagne, 2021; Pakkanen *et al*., 2022). Exploring the psychological motivations underlying serial murder is important to better understand and comprehend serial murder offender's behaviour. Researchers have attempted to understand the underlying motivations of serial murder offenders (Fox & Levin, 2014; Ressler *et al*., 1995; Roberts *et al*., 2007). One method that researchers have utilised is to develop and provide categories on which to base the 'type' or nature of the murder series (Hodgskiss, 2004). By systematically categorising serial murder offences based on the offence type, one

can identify the factors which contribute to the specific and developmental offence patterns (Canter, 2004). Owing to identifiable patterns of behaviour, several classifications or typologies have been developed; some of the most widely recognised will be discussed further in the following section.

2.2.5.1 Organised, Disorganised, and Mixed Typologies

Ressler *et al*. (1986b) initially developed a two-fold classification system and stated that there are two distinct types of serial murderers namely, the *organised* serial murderer and the *disorganised* serial murderer. This typology was developed after FBI agents interviewed 36 convicted serial murder offenders and analysing data from 118 victims (Hazelwood & Douglas, 1980; Ressler *et al*., 1986a). According to the FBI, all serial murderers, regardless of sex, method, or motive, fall into one of these two categories (Ressler *et al*., 1995). This two-fold typology assisted in generating psychological profiles of the offender committing the crime/s as the typology generates inferences which can be made from details of the crime scene behaviour (Ressler *et al*., 1995). It was reported that the *organised* murderer usually is socially and sexually competent, with above-average intelligence, has a stable (often skilled) employment history, and is able to regulate their emotional reactions during the crime (Douglas *et al*., 1986). This implies a high level of ordered thought due to the lack of evidence left behind at a murder scene which is reported to demonstrate a well-planned murder (Douglas *et al*., 2013). The *disorganised* serial murderer type usually exhibits average-to-below-average intelligence, undeveloped social skills, an erratic work history, and a history of sexual dysfunction. The disorganised murderer usually leaves behind a disorderly crime scene, one which is 'sloppy' and does not appear to be well-planned (Douglas *et al*., 1986; 2013).

Douglas *et al*. (2013) reported that some offenders may not be identifiable as being either organised or disorganised due to multiple factors. For example, there may be more than one offender involved, there may be unexpected or unplanned events which occur during the attack, or the victim may fight back and, as a result, there is an escalation in the level of violent behaviour. Therefore, an offender may be classified as being *mixed* if there is poor concealment of the body, despite evidence where there may have been some planning involved. Douglas and colleagues suggest that an offender classified as 'mixed' may be

involved in substance use, is young, the crime scene is usually in disarray, with an excessive amount of manual force, and violence used on the victim (Douglas *et al*., 2013).

Canter *et al*. (2004) strongly suggests that there is a lack of empirical validity to the disorganised and organised typology as these categories are not mutually exclusive, and an offender may exhibit features of more than one of the categories. Canter *et al*. (2004) further argued that the two-fold typology lacks theoretical underpinnings, conceptual analysis, and that human behaviour is too ambiguous and too complex to be classified into one of two specific categories. Furthermore, Canter *et al*. (2004) stated that this typology has suffered from 'the Hollywood effect', as it has become a point of reference and disseminated in popular movies and television shows, which is outdated, and lacks empirical support. This has further compounded the problem, as it has become a conceptual model underpinning psychological profiling and is therefore being utilised in police investigations and court room expert testimony, despite having unsubstantiated theories and models and many methodological flaws in the research (Canter *et al*., 2004; Canter & Wentink, 2004). Additionally, they criticised the development of the additional *mixed* typology, as he argues that it further undermines support for the original dichotomy.

2.2.5.2 Holmes and Holmes Motivation-based Typology

Holmes and Holmes (1998) developed a motivation-based typology, expanded from serial rape typologies. This classification system was used by law enforcement to classify serial sexual offenders in the USA in the 1980s and 1990s. According to them, there are five types of murderers: visionary, mission-oriented, hedonistic, control-oriented, and predatory (Roberts *et al*., 2007; Simons, 2001). *Visionary* sadistic murderers are the most uncommon of the murderers and are usually considered psychotic or insane. The individual has delusions and/or hallucinations which instruct them to kill (Roberts *et al*., 2007). These murders are usually carried out in a specific location or area, victims are usually strangers, are randomly selected, and the method of killing is focused on the act of murder, which is spontaneous and disorganised in nature (Holmes & De Burger, 1985).

According to Holmes and Holmes (2002), the *mission-oriented* sadistic murderer focuses on killing individuals who he/she deems undesirable and feels as though he/she is doing the community a service by eradicating these individuals (Simons, 2001). Mission-oriented

offenders are typically driven to establish a subjective group or regime which they believe is superior to that of others (Roberts *et al*., 2007). Victims are typically strangers, non-random, specifically selected, and the murders are usually carried out in a concentrated or specific geographical location. The method of these murders is planned, organised, and focused on the act (Holmes & De Burger, 1985; Pistorius, 2018).

Hedonistic serial murder offenders murder for the thrill as well as for the pleasure of the crime (Simons, 2001). Roberts *et al*. (2007) state that these offenders are committing these murder/s as an expression of their personal pleasure (Roberts *et al*., 2007). There are three subtypes of hedonistic serial murderers namely lust, thrill, and comfort. *Lust* hedonistic serial murder offender's murder for sexual gratification, victims are strangers, the offenders are organised and have planned the murder as they are process focused, which means that they enjoy the process of planning and carrying out the murder (Holmes & De Burger, 1985). *Thrill* hedonistic serial murder offender's murder for the sensation and thrill such as media sensation, the victims are strangers and non-specific, the murders occur spontaneously and are disorganised while the location is often dispersed (Pistorius, 2018). Lastly, *comfort* hedonistic serial murder offender's murder for financial gain, victims are non-specific, strangers to the offender, the geographical location is often concentrated and committed in a specific area while the method of the murder is planned, organised, and focused on the act of murder itself (Holmes & Holmes, 2002).

Control-oriented serial murder offenders receive gratification and pleasure from having power over their victims. They develop a fantasy about having complete power and control over their victims' destiny and have a need for attention. Although victims are strangers to offenders, they are specifically selected based on certain qualities or physical attributes. The murders are organised, planned, and process-focused, while the geographical locations of crime scenes are often dispersed (Holmes & Holmes, 2002). *Predatory* sadistic murderers are attracted to the 'hunt' and subsequent murder of the victim. They view murder as a sport or recreational activity (Simons, 2001).

Canter and Wentink (2004) attempted to validate the model of Holmes and Holmes (2002) through empirical validity; however, they did not find support to validate or support the categorisation. Hodgskiss (2004) also found that this typology may not be valid or applicable to serial murder offenders in South Africa, as the expressed motives and characteristics of

the crime scenes contradict the inferences suggested by the Holmes' model. Salfati and Bateman (2005) further stated that the Holmes and Holmes model is too vague, and that there is often an overlap between one or more of the behaviours under each typology.

2.2.5.3 Keppel and Walter's (1999) Classification System

Keppel and Walter (1999) extended the Groth *et al*. (1977) rape classification system to include serial sexual murder/murderers. Keppel and Walter (1999) postulated that serial sexual offenders such as murderers and rapists, are motivated by either power or anger. These two underlying motivations resulted in the development of four types: anger retaliation, power-assertive, anger-excitation, and power-reassurance (Bennell *et al*., 2013).

Keppel and Walter (1999) suggest that the *power assertive* rape murderer identifies as being superior to others and wants to show and exhibit this superiority to his victim. Although the offender plans to rape their victims, the offender does not necessarily plan to murder them; however, because of the increase in aggression needed to control the victim, they accidentally cause the victims death (Bennell *et al*., 2013). The *power-reassurance* rape-murderer needs to assure himself that he is in control and that he is powerful. However, Keppel and Walter (1999) argue that the offender cannot fulfil this fantasy, often due to impotence, and thus, to reassure himself that he is powerful and in control, ends up murdering the victim despite this not being the initial plan or primary motive. Keppel and Walter (1999) argue that the *anger-retaliation* rape-murderer has an underlying hatred and anger towards women and, as a result, plans to both rape and murder their victim. The murders are usually excessive in aggression which is used to exhibit an overkill, and sexual assault and rape are violent. Keppel and Walter (1999) postulate that the *anger-excitation* rape-murderer derives sexual satisfaction and pleasure from the suffering of the victim, and the offender plans to rape and murder the victim prior to the attack.

One of the notable criticisms of this model is that it is limited to serial sexual murders, and not all serial murderers are sexually motivated (Salfati *et al*., 2015). Furthermore, Bennell *et al*. (2013) attempted to validate Keppel and Walter's (1999) model through empirical validity. They found no evidence to support the four themes of serial sexual murderers. They reported that they did not find high co-occurring characteristics and behaviours in the model and further argued that this suggests that the model is invalid (Bennell *et al*., 2013). Although

Keppel and Birnes (1998) suggested that typologies are solely theoretical exercises, Hodge (2000) argued that typologies and classification systems have been useful in offender profiling by linking an offender's characteristics to crime series. To address the lack of empirical support for the above-mentioned classification systems and typologies, Salfati and Bateman (2005) developed a thematic based classification of murders through empirical studies.

2.2.5.4 Instrumental and Expressive Murders

Salfati (2000) described *expressive* versus *instrumental* categories of murder. *Instrumental murders* are due to the underlying motivations of money or sex and is typically linked to theft, robberies, violence, or burglaries. Victims' bodies are not hidden, and biological or forensic evidence is left behind, such as traces of blood, semen, or weapons. Salfati and Bateman (2005) postulate that personal gain is the main driving force and motivation behind instrumental aggressive murderers, which results in the victim being used as an object to achieve this, and a 'means to an end'. Whereas *expressive murders* are typically linked to physical attacks, rape, and arson (Salfati, 2000). The offender/s will mutilate, dismember, and use extreme violence, using multiple weapons and/or strangulation/suffocation (Roberts *et al*., 2007). Expressive murderers usually derive pleasure and satisfaction through the interaction with the victim as well as harming the victim (Canter, 2004). Although empirical studies provide numerous benefits, these two categories are not specific or exclusive to serial murder, are criticised for being too broad, and have yet to adequately incorporate situational influences (Snook *et al*., 2008).

Despite the typologies and classification systems, serial murder offenders are considered a heterogenous and complex group of offenders (Pakkanen *et al*., 2021). As a result, serial murder is difficult to understand (Canter, 2004; Bennell *et al*., 2013; Hickey, 2013; Holmes & Holmes, 2002). In addition, studies have examined whether there are cross cultural differences among serial murder offender's behaviour, and whether these typologies are generalisable. For example, Hodgskiss (2004) argues that some of these typologies are not applicable or generalisable when applying them in the South African context, as level of education, poverty, employment record, vehicle ownership, are dissimilar to what has been found amongst the US serial murder population. As a result, the following section will explore serial murder studies conducted in the South African context, comparing similarities

and differences between other countries through examining characteristics of serial murder offenders, crime scene actions, and offending behaviour.

2.2.6 Serial Murder in South Africa

In South Africa, the earliest official record of a serial murder offender was in 1936 where the offender, Cornelius Burger, murdered five sex workers in separate incidents, after having contracted a Sexually Transmitted Infection (STI) (Boberg, 1957; Labuschagne, 2021; Pistorius, 2012). However, shortly after the international development of theoretical concepts and research into serial murder, South Africa began to see an increase in the number of cases in the 1990s (Labuschagne, 2021). This does not suggest that serial murder did not occur before; however, it does give rise to an understanding and exploration of serial murder offenders and the environment (Hodgskiss, 2004; Labuschagne, 2001). According to Hodgskiss (2004), "serial murder functions as a symptom of highly disruptive or badly managed social change" (p. 72). Haggerty (2009) suggests that serial murderers did not develop solely due to individual psychopathology and proposed six social and cultural preconditions in which serial murder offenders flourish. Haggerty (2009) suggests that poor social connection and increased social isolation; the fascination in celebrity culture and the growth of mass media; a society with a strong emphasis on individuality which celebrate individual achievements; the belief that society can be engineered; cultural denigration and an increased tolerance for violence; and increased victimisation opportunities (Haggerty, 2009).

Haggerty (2009) further indicated that there are certain conditions in the environment in which serial murder flourishes such as social inequality, poverty and, political unrest. South Africa has a number of these conditions especially due to the social unrest and political upheaval experienced during apartheid, and rapid change in society from apartheid to post-apartheid era which resulted in high rates of urbanisation and mobility (Labuschagne, 2021). Poverty further compounds the issue as it enables serial murder offenders to engage with victims more easily, as the offer of employment is a common tactic used to easily lure victims away to secluded locations (Hodgskiss, 2004; Labuschagne, 2021; Sorochinski *et al*., 2015; Woodhams & Labuschagne, 2012b). In addition, the high crime rate in South Africa suggests that a significant amount of the population has been exposed to violence and crime (Hodgkiss, 2004). The overall high rates and increase in crime, as well as poor and/or

ineffective government services, enable a breeding ground for anonymity, an environment in which serial murder offenders thrive (Hodgkiss, 2004; Labuschagne, 2001).

2.2.6.1 Studies of Serial Murder in South Africa

There has been a small, yet growing body of academic research examining serial murder in South Africa (De Wet & Potgieter, 2015; Horning *et al*., 2015; Labuschagne, 2006; Labuschagne & Salfati, 2015b; Sorochinski *et al*., 2015), many have been unpublished Master's and Doctoral research studies (Barkhuizen, 2006; Collaros, 2019; Del Fabbro, 2006; De Wet, 2006; Hodgskiss, 2001; Labuschagne, 1998, 2001; Pistorius, 1996, 2018). The first study on serial murderers in South Africa was conducted by Micki Pistorius in 1996. Her Doctoral study examined the origin and development of male serial murderers according to a psychodynamic framework, namely, Freud's theory of psychosexual developmental phases and the typology of the psyche, using two South African cases (Pistorius, 1996). Thereafter, Labuschagne (1998, 2001) examined the interactional style of serial murderers by applying an interactional theoretical framework in his Masters and Doctoral studies. Labuschagne (2001) suggested that serial murder is a result of the communication and interaction with others. Therefore, it is an interaction or communication *between* a person, event, or 'thing', which varies from case to case. Hodgskiss (2004) focused on the behavioural characteristics of South African serial murders. He conducted his research on comparing the application of classification systems on South African serial murder offenders based on the classification systems utilised internationally. Del Fabbro (2006) analysed serial murder from a family systems theory approach in her unpublished Doctoral research. The aim was to further explore the development of a serial murderer within the South African context (Del Fabbro, 2006).

Ultimately, four of these studies had an underlying similarity: that the aetiology of the serial murderer is located from within the offender. Hodgskiss (2001, 2004) interviewed serial murder offenders (n = 13) to examine characteristics and behaviours, later comparing the findings to international typologies. De Wet (2006) interviewed two (n = 2) serial murder using a psychosocial approach (2006), while Barkhuizen (2006) used an interpsychic object relations approach. Most recently, Collaros (2019) examined the psychogeography of serial murder offenders (n=15) through a qualitative approach using semi-structured interviews. Knight (2007) succinctly states:

> All of these theories go in some way to contribute to the conceptualisation of serial killers' behaviours, but in isolation they maintain a focus on certain aspects while necessarily ignoring other aspects. It is for this reason that there is a consensus that what makes a serial killer is a combination of many complex and interrelated neurological, social, physiological, environmental, and psychological factors (p. 22).

To date, the largest study of serial murder offenders in South Africa and their crime scene behaviours was conducted by the SAPS IPS in South Africa in collaboration with the John Jay College of Criminal Justice Department of Psychology, which is a senior college of the City University of New York (CUNY) (Horning *et al*., 2015; Labuschagne & Salfati, 2015; Salfati *et al*., 2015a, 2015b; Sorochinski *et al*., 2015). The sample consisted of 33 solved murder series which occurred between 1952 and 2007 and made use of police case files which increased ecological validity of the findings of these studies (Labuschagne, 2021). Data were coded using the *Homicide Profiling Index* © (HPIv4). These studies examined the characteristics and behaviour consistency of victims, offenders, and crime scene actions some of which will be discussed next.

2.2.6.2 Victims, Offenders, and Offence Characteristics

While the stereotype of serial murder offenders is that they are highly intelligent, single White males (Yaksic, 2023), the public's perception of serial murder developed predominantly through outdated research, entertainment, and the media, which have then been converted into stereotypes (Yaksic 2023). For example, serial murderers in South Africa were found to be 66.7% Black, 24.2% White, and 9% Coloured (Salfati *et al*., 2015b). The majority of the offenders (60%) were in relationships, and only 39% were single (Horning *et al*., 2015). With regard to employment, at the time of arrest, 34.5% were unemployed, while 55.2% were employed as labourers (Horning *et al*., 2015). Only 38.3% had a high school level of education and almost all (89.3%) of the serial murder offenders in the sample had a criminal history (Horning *et al*., 2015). Offence histories ranged from violent (57.1%), sexual (35.7%), property-related (64.3%), and 'other' types of previous criminal histories (35.7%) (Labuschagne, 2021). This demonstrates the *criminal versatility* of offenders which means that offenders are able, and do, commit other types of crimes, and do not stick to certain crime type (Turvey, 2012a). As a result of previous criminal histories and prior offence experiences, offenders may gain forensic awareness and therefore, use

avoidance and detection strategies to evade further arrests (Chopin *et al*., 2019, 2020; Eichinger & Darjee, 2021; Reale *et al*., 2020, 2021).

Labuschagne (2021) states that the demographics of serial murder victims reflect the proportions of the country's demographics. In the largest study of South African victims of serial murder offenders, Horning *et al*. (2015) and Sorochinski *et al*. (2015) found that the majority of victims were Black (77.5%), unlike in the US where 50-70% of victims were White and only 35.9% were Black (Sorochinski & Salfati, 2010). Similarly, victims of serial murderers in France and Canada were also found to be predominantly White (James *et al*., 2018). However, in the South African sample, White victims compromised only 7.7% of the sample and 11.7% were Coloured, 2.3% were Indian, and only 0.7% were Asian (Salfati *et al*., 2015b). This highlights the differences found between countries with regard to victim demographics, as a result of the ethnic and racial composition of each country (Chopin & Beauregard, 2021a). In the South African sample, most of the victims in the sample were female (64.9%) and 35.1% were male (Salfati *et al*., 2015b). This is consistent with findings from the USA where the majority of victims in the sample were female (81%) and 18.5% were male (Sorochinski & Salfati, 2010). Not all offenders murdered all their victims in the South African sample, and 51.5% of offenders had at least one surviving victim in a series, which is consistent with Sorochinski and Salfati (2010) study where 19.3% of victims survived.

Sorochinski *et al*. (2015) found that cultural factors impact on the planning of serial murder offenders in the South African context in comparison to other countries such as the USA. They found that most of South African serial murderer's crime scenes occurred outside (78%) for example in open veld/grounds (Sorochinski *et al*., 2015), whereas the majority of serial murders in the USA and Canada occurred in urban areas and in structures such as buildings (Hickey, 2016; James *et al*., 2018). Whereas in Korea, victims of serial murderers were mostly found within their residences (Sea *et al*., 2019). For South African offenders, outdoor locations are likely due to the highly compacted, urban areas such as informal settlements, and high levels of security measures such as guarded community living areas as a result of the high crime rate in South Africa (Hodgskiss, 2004).

South African serial murderers were also found to be from low-income groups and therefore, did not have access to vehicles (Salfati *et al*., 2015a). As a result, it is necessary for offenders

in South Africa to lure victims to (often preselected) isolated locations, to reduce the chances of being heard or seen (Labuschagne, 2021; Sorochinski *et al*., 2015). Due to these isolated outside locations, there is often a delay in recovering victim's bodies (Labuschagne, 2021). Consequently, there is often degradation of forensic and physical evidence due to the natural environment of South Africa such as high temperatures (which increase rates of decomposition of the body), as well as animal activity such as scavenging (Sorochinski *et al*., 2015). The above examples highlight how cultural differences across countries can impact on serial murder offence characteristics and crime scene behaviours (Chopin & Beauregard, 2021a).

South African serial murder offenders were found to either plan the murders in advance, or not at all and generally had two location sites for committing their crimes in comparison to the USA who have three locations and took part in pre- and post-planning (Sorochinski *et al*., 2015). In South Africa, the first location is the one where the offender meets the victim (Hodgskiss, 2004), and the second location is where the offender ultimately lures the victim to murder them, leaving their bodies at the same location (Sorochinski *et al*., 2015). This is different to serial murder offenders in the USA where there are three locations which are important for the offender (Hickey, 2016). The first location is where they meet the victim, the second location is where they murder the victim, and the third and final location is the body disposal site (Sorochinski *et al*., 2015). In South Africa, most serial murder offenders brought their weapons to the scene (76.1%) contrary to Sorochinski and Bateman (2005) where a weapon was brought to the scene in 43% of cases in the USA. Salfati *et al*. (2015b) found that in their study on South African serial murder victims; 30.2% victims were murdered from gunshots, 27.6% were murdered by blunt force, 25.7% were strangled, and 10.8% were stabbed.

The Salfati *et al*. (2015b) study found that the average age of victims of serial murders in South Africa were 31 years old, which is similar to victims in Europe who were 35 years old in Italy (Pakkanen *et al*., 2015b), 26 years old in Australia (McKinley & Petherick, 2021), and 30 and 27 years old in France and Canada respectively (James *et al*., 2018). Most of the victims were strangers to the offender (73.3%), similar to findings from Hickey (2016) where 70% of victims were strangers to offenders in the USA. Labuschagne (2021) also reports that most serial murders in South Africa have a sexual theme or nature to them (65.7%).

However, Salfati *et al*. (2015b) stated that serial offenders are often motivated by a variety of reasons, and it is not only an inherently sexually motivated crime.

Although sex workers are often targeted by serial murder offenders (Sorochinski & Salfati, 2019), few victims were sex workers (4.5%) in the South African sample (Salfati *et al*., 2015b); whereas 22% of victims of serial murder offenders in the USA sample were sex workers (Salfati & Bateman, 2005). This is likely due to the high unemployment rate within South Africa, as 40.3% of victims in the South African sample were unemployed, and therefore, vulnerable to leave with a stranger offering (false) employment. Victims were often lured away with a con story (47%) by offering false employment, a common MO found within the serial murder sample, and particularly in serial sexual assaults (rape) (77%) (Woodhams & Labuschagne, 2012b).

Vulnerable victims, those with low social control (Egger, 1984; Horning *et al*., 2015; Salfati & Bateman, 2005), such as female victims, children, pensioners, and unemployed persons are consistently selected across serial murder offenders both locally, as well as internationally (Salfati *et al*., 2015a; Sorochinski & Salfati, 2010). These studies highlight the importance of apprehending and linking serial murder offences early on, which leads to the next section of criminal profiling, and most importantly, crime linkage.

2.3 CRIMINAL PROFILING: BEHAVIOURAL EVIDENCE ANALYSIS

Criminal profiling is often referred to as offender profiling, investigative psychology, criminal evidence analysis, psychological profiling, and behavioural investigative advice (Petherick & Turvey, 2012a). Although these terminologies are used interchangeably, they are all classified under the broader term of profiling (Fox & Farrington, 2018). Using principles from the social and behavioural sciences (such as personology and social psychology), criminal profiling uses behavioural evidence as an approach to problem solving, when investigators lack any formal leads (Canter *et al*., 2004; Holmes & Holmes, 2002). Criminal profiling is a form of behavioural evidence analysis which identifies and infers personality characteristics of an unknown offender based on behavioural evidence such as the offender's crime scene behaviour, victim selection, and MO (Alison *et al*., 2010; Canter, 2000, 2010; Douglas *et al*., 1986; Dutta & Banik, 2023; Snook *et al*., 2008).

Criminal profiling is based on two main assumptions namely, the consistency hypothesis and the homology assumption (Woodhams & Toye, 2007). The assumption of homology is the suggestion that there will be a relationship between the crime scene behaviours of an offender and the offender's personal characteristics (Mokros & Alison, 2002). The consistency hypothesis is referred to as the suggestion that people will react and behave in stable yet consistent (similar) ways (Canter, 1994). Criminal profilers assist investigators by identifying and providing the most likely personal characteristics of an offender, such as inferring the underlying personality, likely demographics, and behavioural characteristics, based off the crime actions and behaviours which are evident when analysing the crime scene (Canter, 1994; Crabbé *et al*., 2008; Fox & Farrington, 2018). The characteristics of offenders are based on inferences derived from physical, psychological, emotional, habitual, and vocational factors (Turvey, 2012a).

Insights developed by criminal profiles regarding the offender's state of mind and possible motivations can assist in formulating proactive strategies in preventing future possible crimes by predicting these crimes based on victim selection and geographical locations (Ainsworth, 2000; Crabbé *et al*., 2008; Douglas *et al*., 1986; Holmes *et al*., 1988; Holmes & De Burger, 1985; Ressler *et al*., 1986). Therefore, the goal of criminal profiling is to assist in criminal investigations by providing law enforcement with a description of the type of person/offender who would most likely have committed the offence/offences, based on the crime scene behaviours and actions taken by the offender (Crabbé *et al*., 2008). In addition, to also identify possible motivations of the offender in order to narrow down the suspect pool (Crabbé *et al*., 2008; Goodwill *et al*., 2014; Woodhams & Toye, 2007).

The ultimate purpose of criminal profiling is to assist in investigation and legal processes by narrowing suspect pools and providing insights into the characteristics, motivations, and intentions of the type of individual responsible for committing the crime (Dutta & Banik, 2023; Turvey, 2012a). Criminal profilers can assist investigators by providing suggestions related to the interviewing process and strategies (Labuschagne, 2015b). In addition, during the prosecution phase, profilers can assist by providing similar fact evidence in court by linking cases based on behavioural evidence, as well as suggesting trial strategies of offenders**,** to the prosecution (Petherick, 2006; Petherick, 2009). Furthermore, profilers may provide suggestions to the court regarding sentencing which pertain to the criminal

propensity of the offender, and the level of risk the offender poses at reoffending (Chai *et al*., 2024; Crabbé *et al*., 2008; Labuschagne, 2015b).

Petherick and Turvey (2012b) refer to nomothetic and idiographic approaches to profiling. The *idiographic* approach to profiling is referred to as studying individual crimes such as a specific case and the unique traits which accompany that particular case (Petherick & Turvey, 2012b). The idiographic approach often uses *deductive* reasoning and takes unique behaviours or combination of behaviours into account (referred to as the signature of the offender) by analysing the crime scene and basing profiles on crime scene behaviours, victim profiles, post-mortem reports, crime scene photographs, and witness accounts (Turvey, 2012b). Deductive reasoning is considered time-consuming and is often based on the clinical experience and knowledge of the profiler (Snook *et al*., 2007). As a result, more effort is required from the profiler as it is more detailed and takes into consideration the potential impact of situational factors which may have impacted the offender's crime scene behaviour (Pistorius, 2018; Turvey, 2012a). A limitation of solely using clinical experience is that it is often based on subjective experience and opinions, rather than being based on empirical studies to support the opinions**,** which is important when providing expert evidence to a court (Alison *et al*., 2003; Meyer, 2007).

The *nomothetic* approach to profiling is reported to be abstract, focusing on groups and universal behaviours, using statistical methods to predict the likely behavioural patterns of future crimes (Bennell *et al*., 2015; Petherick & Turvey, 2012b; Snook *et al*., 2007). The nomothetic approach to profiling often uses *inductive* reasoning, as it relies mainly on statistical knowledge and research findings, is more general in nature and less time consuming than deductive reasoning (Petherick & Turvey, 2012b). An example is, examining groups of offenders and identifying subgroups which have common characteristics regarding the 'type' of person likely to commit certain types of crimes (Petherick, 2006). Large, computerised databases have been developed and implemented, such as the Violent Offender Criminal Apprehension Program (ViCAP) and Violent Crime Linkage Analysis System (ViCLAS)**,** to assist with linking crimes (Burrell *et al*., 2024; Rainbow, 2015).

Petherick and Turvey (2012b) report that while the nomothetic approach and inductive reasoning is necessary and useful for generating theories about criminal and offending

behaviour, they should not be used in isolation. Criminal profilers should ideally take both approaches and types of reasoning into consideration, which is referred to as the *structured professional judgement* approach (Bennell *et al*., 2015). The structured professional judgement approach combines the general understanding of offending behaviour such as using large, computerised databases to inform decisions, while examining the particulars of a specific case using practitioner and investigative experience (Bennell *et al*., 2015; Ribeiro & de Matos Soeiro, 2021).

Despite the popularity of criminal profiling among psychologists, criminologists, and behaviourists, the scientific credibility such as the validity and reliability of criminal profiling has been called into question as a result of the lack of findings from empirically based studies to support various assumptions and theories that have been suggested (Fox & Farrington, 2018; Snook *et al*., 2008). The term *criminal profiling illusion* has been used to describe the popularity and consistent use of criminal profiling, despite its lack of empirical and scientific support (Snook *et al*., 2007). For example, the classification and typologies used to define serial murder offenders such as the organised/ disorganised typology have been used in criminal investigations. These, however, lack empirical support as studies have not been able to replicate or validate the findings (Canter *et al*., 2004). As a result, the scientific credibility of criminal profiling and the accuracy of offender profiles has been called into question (Alison *et al*., 2002). Research studies which have tested the reliability, and the validity of previous classification systems suggest that profiles were based on opinions and subjective experiences, rather than empirical and scientific support (Alison *et al*., 2003; Bennell *et al*., 2013; Canter *et al*., 2004; Canter & Wentink, 2004)

To establish a more scientific, evidence-based approach to criminal profiling, Canter (1995) developed the term Investigative Psychology. Investigative Psychology refers to the field of operational and applied psychology which is used across the range of activities related to the analysis, investigation, and prosecution of crimes (Salfati, 2021). Canter and Youngs (2003) state that investigative psychology is based on the A → C equation which is the process of linking crimes based on the actions (A) and behaviours displayed during the crime, to the characteristics (C) of the offender. The focus of criminal profiling, behavioural crime scene analysis and investigative psychology has been inferring the characteristics of offenders, establishing behaviour consistency of offenders based on crime scene behaviours, and identifying subgroups of crime types (Salfati, 2021). The main focus of investigative

psychology is to provide empirically driven theories based on scientific evidence and support (Salfati, 2019).

To evaluate the reliability and validity of criminal profiling, Fox and Farrington (2018) conducted a systematic review, which consisted of 426 publications on criminal profiling over the past four decades. They found that the scientific and statistical rigor of criminal profiling has increased from 0% to 33% over 40 years, and that the number of peer-reviewed publications were three times that of non-peer-reviewed studies (Fox & Farrington, 2018). Furthermore, the vast majority of literature which has been produced on criminal profiling in the past two decades has emanated from academics. According to Fox and Farrington (2018), this is crucial in developing and maintaining a scientific and empirically based discipline. This is important to note, as criticism of criminal profiling is that it lacks empirical research to support the assumptions fundamental to the scientific methods and techniques used (Labuschagne, 2015b; Rainbow *et al*., 2014; Snook *et al*., 2008). Despite recent developments in the past two decades in improving the scientific rigour of criminal profiling, there is still a lack of synthesis and agreement regarding terminology, methodologies, and findings on criminal profiling (Fox & Farrington, 2018).

Fox and Farrington (2018) suggest that the lack of credibility associated with criminal profiling is as a result of the lack of consistency and uniformity with regard to various aspects of profiling, such as the basic terminology, methods, and data, which criminal profiling research has been utilising. Fox and Farrington (2018) suggest that for criminal profiling to be recognised as a scientific discipline, researchers should aim to scientifically test, replicate, and consolidate the terminology to update and advance the field of criminal profiling. Rainbow (2015) states that research and practice should not be seen as distinct and separate practices. Therefore, in order or integrate the two, the Crime Linkage International Network (C-LINK) was formed in 2015 to assist in enhancing collaboration and reduce the gap between practitioners and researchers (Bennell & Woodhams, 2015). The collaboration between research and practice is necessary for empirical research to inform practice as well as for practitioners and clinicians investigative experience to inform research (Rainbow, 2015).

As a result, there is a growing body of literature and research focused on using scientific methods as well as objective and replicable measures in certain subfields of criminal

profiling. This includes evidence-based profiling (Fox & Farrington, 2018), crime linkage (Bennell *et al*., 2014; Bennell & Canter, 2002; Woodhams & Davies, 2021), and investigative psychology (Alison *et al*., 2010; Bull, 2019; Canter, 2000; Canter, 2004). Investigative psychology has been implemented and applied in South Africa and has been able to link crimes successfully based on behavioural evidence (Labuschagne, 2012; 2015).

2.3.1 Criminal Profiling in South Africa

Within the South African context, the SAPS formed the Investigative Psychology Unit (IPU), with a single counselling psychologist employed within the unit in 1997, for the purpose of providing formal profiling services for SAPS investigations (Pistorius, 2018). In 2011, the unit expanded into the IPS and by 2020, more than 44 individuals were employed under the section which included various professionals, such as investigators, criminologists, psychologists, and researchers (Labuschagne, 2021). SAPS, therefore, have one of the largest investigative sections in the world for investigating psychologically motivated crimes (Labuschagne, 2021). Psychologically motivated crimes are considered to be crimes which are not economically driven such as cash-in-transit robberies or vehicle hijackings (Labuschagne, 2021b).

The IPS often assist in investigations of crimes which are not motivated by external factors such as financial motives (Labuschagne, 2021b; Labuschagne & Salfati, 2015). Psychologically motivated crimes such as serial rape, serial murder, child murder, muti-murders, intimate partner murders, child sex offences, sexual murders, and kidnappings are investigated by the IPS (Labuschagne, 2021). The IPS have been instrumental in training of SAPS members, investigating and assisting in solving crimes, and providing research for international and local studies particularly, examining the characteristics and offence behaviours of serial rape and murder series (Horning *et al*., 2015; Labuschagne & Salfati, 2015; Salfati, *et al*., 2015b; Salfati, 2015; Sorochinski *et al*., 2015; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a; 2012b). SAPS IPS is involved in solving multiple types of crimes by providing expert testimony, risk assessments, sentencing reports for legal processes, interviewing offenders and victims, crime scene analysis, as well as conducting research into topics such as serial rape, and serial murder within the South African context (Labuschagne 2012; 2015a; 2021).

Criminal profiles are primarily created as investigative tools and are useful in identifying patterns of behaviour (Labuschagne, 2012). These profiles also assist investigative units/sections such as the SAPS by providing similar fact evidence through linking potentially related crimes based on crime scene behaviours (Labuschagne, 2012, 2021; Petherick, 2006). According to Grubin *et al*. (2001), if crimes can be linked to the same offender/s through crime scene behaviour/s, then it is reasonable to suggest that certain behaviours remain consistent across a crime series, or they at least develop or evolve in a particular way. One subcategory of criminal profiling is crime linkage, which is discussed below, and the approach used in this study.

2.4 CRIME LINKAGE

Crime linkage, also referred to as case linkage or linkage analysis, links two or more crimes to the same offender based on similar yet unique crime scene behaviours (Bennell & Canter, 2002; Labuschagne, 2012; Woodhams *et al*., 2007; Woodhams & Toye, 2007). Crime linkage is a form of criminal profiling and behavioural analysis, and the method used when crime scene behaviour is analysed within a particular series of two or more crimes (Hazelwood & Warren, 2003; Woodhams & Toye, 2007). Although forensic and physical evidence is the most concrete and reliable way of connecting crimes, this type of evidence may not be available, or may be absent or missing from the crime scene (Canter, 2004). As a result, law enforcement officials such as investigators, needs alternative valid and reliable ways of connecting crimes, of which behavioural evidence is considered to be constantly present and obtainable (Davidson & Petherick, 2021; Woodhams *et al*., 2007). The two underlying principles of crime linkage are that offenders behave in similar, and consistent ways across crimes, yet their crime scene behaviours are distinct and unique enough to differentiate them from other offenders committing similar types of crimes (Bennell & Canter, 2002; Woodhams & Toye, 2007).

Woodhams and Bennell (2015a) refer to the proactive and reactive approach to crime linkage. The proactive approach, also known or referred to as *comparative case analysis* involves the active searching of a database to identify behaviour commonalities and similar behaviours between offences (Rainbow, 2015; Woodhams & Bennell, 2015a). However, the profiler or behavioural analyst does not suggest whether the cases are linked or not to the same offender, and is instead searching for behavioural commonalities (Turvey, 2012b). The

reactive approach on the other hand, is often referred to as *case linkage* and *crime linkage analysis*, which is when a behavioural analyst or criminologist is provided a set of cases which investigators seek advice on determining whether the cases are linked or not, based on similar yet unique features of the crimes (Rainbow, 2015). The ability to link cases and provide investigative advice is based on the underlying behaviour consistency and distinctiveness of an offender's crime scene behaviour (Bennell & Canter, 2002). Therefore, the purpose of crime linkage is to establish whether a crime is part of a series which has been committed by the same unknown offender/s, thereby linking crimes and cases to a particular crime series (Woodhams *et al*., 2019).

2.4.1 Theoretical Assumptions: Behaviour Consistency and Distinctiveness

As mentioned, the two underlying principles, or assumptions, of crime linkage are that an offender's behaviour is consistent over time, and that each offender's behaviour has a degree of distinctiveness or uniqueness in the crimes which they commit (Davidson & Petherick, 2021; Labuschagne, 2012; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). In other words, the crime scene behaviour is unique and distinct enough so that it can be distinguished from offender's committing similar crime types, yet similar enough in behaviour that it can be recognised across a series of offences (Bennell *et al*., 2014; Davies & Woodhams, 2019).

Behaviour consistency has been studied through the lens of social psychology and personality psychology (Alison *et al*., 2002; Woodhams & Bennell, 2015b). To summarise, the main focus of social psychology was on how the situation influences an individual's behaviour, whereas personality psychology's main focus was on the individual, and how individual stable personality traits influence the behaviour of a person (Woodhams & Bennell, 2015b). Hodge (2000) suggests that the interpersonal style of an individual is consistent over time and is reflected in their everyday behaviour. Initially, personality theorists suggested that an individual would react in stable and consistent ways across situations however, this hypothesis was not supported by findings of empirical studies, which showed variability in behaviour in response to different situations (Barenbaum & Winter, 2008; Mischel & Shoda, 1995). For example, serial murder offenders are known to exhibit particular crime-scene behaviours and patterns of behaviour across crimes however,

there has been variability in the data which is important to consider and understand (Bateman & Salfati, 2007; Hazelwood & Warren, 2003; Salfati & Bateman, 2005).

Mischel and Shoda (1995) suggest that personality is a system which interacts with cognitive and affective processes which means that it is dynamic, and can therefore, change according to the situation (Mischel & Shoda, 1995). To explore this situation further, Mischel and Shoda (1995) developed the Cognitive-Affective Personality System (CAPS) model to understand the stability of an individual's behaviour as well as the variance in behavioural expressions of personality (Mischel & Shoda, 1995). They sought to understand how the interaction of the person *and* the situation influence and individual's behaviour (Woodhams & Bennell, 2015b). Mischel and Shoda (1995) suggest that, based on learnt experiences, individuals will respond in similar ways to situations by activating previously used cognitive and affective strategies. As a result of individual learnt experiences, the cognitive strategies and subsequent behavioural responses are considered unique to each person (Mischel & Shoda, 1995).

This model is relevant and beneficial for the purposes of crime linkage in order to understand and conceptualise the variability found in offending behaviour (Canter *et al*., 2004; Woodhams & Bennell, 2015b; Woodhams & Toye, 2007). Although individual behaviours may differ, there may be an underlying consistency with regard to the way in which an individual responds to situations, based on cognitive strategies and affective components used when responding to situations which remind the offender of previous learnt experiences (Bennell *et al*., 2021; Mischel & Shoda, 1995). This results in an offender responding in similar ways which are unique to them. According to Canter and Youngs (2009) and Labuschagne (2015), individuals often react to situations in stable, yet unique ways of reacting to situations, which Canter (1994) termed the consistency and learning hypothesis.

How consistently an offender exhibits the same or similar behaviour across their crime series is significant in understanding the behavioural evidence for the purpose of linking crimes (Bennell *et al*., 2015; Sorochinski *et al*., 2015; Sorochinski & Salfati, 2010; Woodhams *et al*., 2019). Therefore, crime linkage combines information and integrates various aspects of an offender's crime scene pattern of behaviour such as the offender's signature, MO, and fantasy-based or ritual behaviours displayed by the offender during the crime (Labuschagne, 2012; Van der Watt *et al*., 2014). Each of these are relevant in understanding the behavioural

consistency and uniqueness of serial murder offender's crime scene behaviour which can be used to link an offender to a series of crimes (Hazelwood & Warren, 2003; Labuschagne, 2012).

2.4.1.1 Victimology

Victimology is described as the comprehensive history of an individual who has become a victim of crime (LaBrode, 2007). According to Schneider (2001), people are not born victims, but are rather associated with certain lifestyles, as well as continuous reoccurring behaviour in which an individual may find him/herself in vulnerable situations, where there is a high risk of becoming a victim of crime. According to Ressler *et al*. (1995), victimology has become one of the most valuable tools for classifying and solving violent crimes due to the consistency among victim selection within a series, as victims of serial offenders often share common characteristics within a series (Mouzos & West, 2007b). Research has focused on victimology as it is understood to be important to understand why a victim was selected or identify similarity of characteristics such as the type of victims within a series of crimes which a serial offender target. Once this is done then a profile can be compiled of the likely offender and possible apprehension of the offender can take place (LaBrode, 2007; Pistorius, 2018; Salfati, 2019). Therefore, analysing victim characteristics could reveal possible similar characteristics which assist in preventative strategies by identifying who, why, or where, the serial offender may likely target next (Rainbow, 2015; Salfati, 2019).

Victimology assists criminal investigations by linking separate crimes or crime scenes to a single offender, as serial offenders appear to be consistent in the types of victims they target across crimes (Hickey, 2016; Horning *et al*., 2015; Ressler *et al*., 1986b; Woodhams & Labuschagne, 2012a). Victimology is considered to be consistent across crimes as the choice of target is who the offender chooses to target is considered to be within the control of the offender, and less susceptible to external influence (Bateman & Salfati, 2007; Bennell *et al*., 2021; Horning *et al*., 2015; Salfati *et al*., 2015a; Salfati, 2015; Salfati, 2019; Salfati & Bateman, 2005).

Although serial murder offenders appear to target similar victims across crimes, research suggests that there is variability within an offender's murder series (Salfati *et al*., 2015a; Sorochinski & Salfati, 2019), and some serial murder offenders may select different types

of victims within a series (Sorochinski & Salfati, 2010). For example, serial murder offenders were found to not consistently targ*et al*l or only sex workers within their series, and that victims of different ages and employment statuses were also targeted within a series (Sorochinski & Salfati, 2010, 2019). However, while there may be variability among serial offender's target selection behaviours, vulnerable victims, such as those with low social control (Egger, 1984; Horning *et al*., 2015), appear to be consistently targeted among serial murder offenders across countries such as South Africa, USA, and Italy (Pakkanen *et al*., 2021; Salfati *et al*., 2015a; Santtila *et al*., 2008).

To understand the variability among victimology within an offender's series further, Canter (1994) provided a model for understanding the underlying dynamic between the interaction between the victim and the offender by basing the interaction on the assigned psychological meaning. Canter (2002) suggests that the way in which an offender interacts with the victim is largely due to the role they ascribe to the victim, and as a result, consistency of behaviour may be victim specific. The three main roles identified by the model are victim as vehicle, victim as person, and victim as object (Sorochinski & Salfati, 2010). *Victim as person* is usually when the victim represents some unique importance to the offender (Salfati, 2015). *Victim as object* is when the victim is depersonalised, and where the offender is focusing solely on their own actions towards doing things to the victim (Salfati, 2015). *Victim as vehicle* is when the victim is used as a 'means to an end' for the offender to satisfy their own needs (Salfati *et al*., 2015a).

Therefore, despite the apparent lack of consistency among victim types, there appears to be consistency in behaviours which are related to specific victims within a series, and therefore, there is behaviour consistency which is victim specific (Salfati, 2019; Sorochinski & Salfati, 2010). Victimology and crime scene actions are considered the most reliable ways of connecting and linking crimes as they are considered to be behaviours which the offender is able to control and plan, and less susceptible to influence from situational factors (Bateman & Salfati, 2007; Salfati, 2019). For this reason, it is important to consider other aspects of the crime and crime scene behaviours such as the MO, and crime scene behaviours which may provide further insight into the interaction with the victim to establish behaviour consistency and distinctiveness which are important to link crimes (LaBrode, 2007; Salfati, 2019).

2.4.1.2 Modus Operandi

Modus operandi (MO) is derived from the Latin term and means 'method of operating' (Turvey & Freeman, 2012a). MO can be described as behaviours which allow the offender to evade detection and thereby commit the crime successfully (Keppel, 2000; Labuschagne, 2012; Labuschagne & Salfati, 2015). In other words, MO is how, and the way in which an offender commits a crime, and the practical and functional means of committing a crime (Hazelwood & Warren, 2003; Van der Watt *et al*., 2014). If an offender is able to commit a crime and go undetected, it is likely that they will continue to commit similar types of behaviours, as they are able to expect or anticipate certain results and outcomes (Gee & Belofastov, 2015; Woodhams & Toye, 2007). Therefore, because the offender has successfully committed the crime undetected, there is consistency in their MO crime scene behaviour (Hazelwood & Warren, 2003; Van der Watt *et al*., 2014). The repetitive nature of the offender's behaviour creates a sense of familiarity and control, which enables a sense of confidence, thus resulting in a fine-tuned focus on the motive of the crime to fulfil the psychological and physical needs of the offender (Hazelwood & Warren, 2003).

However, MO is considered a learned behaviour (Hazelwood & Warren, 2003). As a result, the MO may change and evolve as the offender matures or gains more experience, such as becoming more forensically aware (Beauregard *et al*., 2022). For example, an offender may increasingly gain a better understanding of the importance of forensic evidence such as ballistics, DNA, fingerprints, and closed-circuit television (CCTV) footage in police investigations (Reale *et al*., 2020). This is applicable especially to those who have a criminal history as they have had previous contact with law enforcement (Beauregard & Bouchard, 2010; Beauregard & Martineau, 2014). Furthermore, Chopin and Beauregard (2021b) found that serial offenders displayed more forensic awareness than once-off offenders. As a result of this forensic awareness, offenders used avoidance and detection strategies to evade detection and discovery (Beauregard & Bouchard, 2010; Chopin & Beauregard, 2021b). For example, an offender who has previously been convicted for sexual assault through DNA evidence which connected him to the crime from seminal fluid found on a victim, may as a result, start using condoms; or an offender whose fingerprints were found at a crime scene may start wearing gloves at a crime scene, turn their mobile phone off so that they cannot be tracked or traced by signal towers, and cover their face to conceal their identity (Chopin *et al*., 2022; Chopin & Beauregard, 2024; Reale *et al*., 2022).

However, as an offender begins to grow in confidence and experience in committing crimes successfully without being discovered, their MO is unlikely to change and/or evolve (Beauregard *et al*., 2022; Chopin *et al*., 2022; Douglas & Munn, 1992). Internal factors which may impact on an offender's MO include age, maturity, education, life experience, mood, and substance use (Turvey & Freeman, 2012a). Situational factors and external circumstances which may impact an offender's MO include the interaction with the victim such as, the behavioural response of the victim, victim availability, and the interruption of the crime by a witness (Douglas & Munn, 1992; Hazelwood & Warren, 2003; LaBrode, 2007; Turvey, 2012a).

The method of luring victims away with a 'con story' by falsely offering employment has been a highly effective MO for serial offenders in South Africa (Hodgskiss, 2004). The results of the con-story were also found in Woodhams and Labuschagne (2012b) study on victims of serial rape. Interestingly, the first recorded South African serial murderer's MO in 1936 is notably similar to current day MO exhibited by current serial murder offenders (Labuschagne, 2006; 2021). This similar type of MO namely, using a ruse to lure vulnerable victims, is also consistent with Beauregard *et al*. (2022) analysis of MO.

There may be a change in the usual pattern of violent behaviours such as an increase in the levels of aggression (escalation) displayed at the crime scene (Salfati, 2019), or changes in various MO behaviours, as serial offenders are said to act out 'trial runs' of their underlying fantasy (Van der Watt *et al*., 2014). For example, even though an offender may fantasise about committing certain sexual acts or levels of violence, they may only start to act those out later in their series as they start to gain more confidence, as a result of not being apprehended, and remaining undetected (Crabbé *et al*., 2008; Van der Watt *et al*., 2014). Although some crime scene behaviour may be viewed as typical in criminal MO behaviour, it is the *combination* of these MO behaviours where a unique signature, trademark, or ritual may be identified (Labuschagne, 2006, 2012). Therefore, the change in an offender's behaviour can also be vital to investigators for linking purposes to suggest that a crime is likely to have been committed by the same offender due to the unique combination of crime scene behaviours (Douglas & Munn, 1992; Hazelwood & Warren, 2003; Labuschagne, 2012).

2.4.1.3 Fantasy and Ritual

Fantasy is relevant because it is reported to be the underlying intention and blueprint for the behaviour, and as the offender tries to repeat the fantasy, there is similarity/consistency displayed in crime scene behaviour across crimes (Keppel, 2000). The fantasy is also unique to the offender, and as a result, the crime scene behaviours that manifest from the fantasy are unique, distinguishing them from other offenders who commit similar types of crimes (Hazelwood & Warren, 2003; Van der Watt *et al*., 2014). Although ritualistic behaviour may evolve, or more evidence thereof may be exhibited during the crime, as the offender gains confidence, the theme will persist (Crabbé *et al*., 2008). Fantasy is reportedly more useful at linking crimes with offenders who plan their offences, rather than impulsive offenders (Hazelwood & Warren, 2003).

Unlike the MO which is largely functional, ritual behaviour/s serve to act out the internal psychology and fantasies of the offender (Hazelwood & Warren, 2003). The fantasy of an offender often plays a significant role in psychologically motivated crimes such as serial murder offenders. Ritualistic behaviour is symbolic and unique to the fantasy of serial murder offenders (Hazelwood & Warren, 2003; Van der Watt *et al*., 2014). However, ritual behaviour may evolve or escalate as the offender loses control at the frustration of not being able to achieve the fantasy (Sorochinski & Salfati, 2010). For example, the level of violence used in a crime to achieve the same psychological intensity or experience (Hazelwood & Warren, 2003). Although ritualistic behaviour may be unnecessary to successfully commit the crime, it is highly significant for the offender to express their primary fantasy and motivation for the crime in order to satisfy their psychological gratification and purpose (Crabbé *et al*., 2008; Hazelwood & Warren, 2003; Schlesinger *et al*., 2010).

According to Hazelwood and Warren (2003), the offender's fantasy will impact the choice of behaviours which they use to control the victim, the violence the offender inflicts on their victim, and the verbal interaction between the victim and offender by what is said to the victim. This is also why it is important to consider the model proposed by Canter regarding the interaction with the victim, as the behaviours may be consistent with specific victims (Sorochinski & Salfati, 2010). As mentioned previously, serial offenders are said to have 'trial runs' (Van der Watt *et al*., 2014). Therefore, as the offender gains confidence in playing out their fantasy, they may discover different fantasies as they experiment in different crimes

which could account for the variability of an offender's crime scene behaviour/s (Salfati, 2019; Van der Watt *et al*., 2014). In addition, they may also become more confident as they are able to successfully evade detection and apprehension, which could account for the change and variability in some of the behaviours which may not be necessary in order to complete their crimes (Salfati, 2019).

2.4.1.4 Signature

The signature of an offender is described as the unique combination of behaviours which are evident in two or more crimes, which suggest that the same individual/s are responsible for a series of crimes based on the distinct crime scene behaviours (Bateman & Salfati, 2007; Hazelwood & Warren, 2003). The signature of an offender is an action which is not necessary to commit the crime, however, it is an action which satisfies the internal emotional and psychological needs of the offender (Crabbé *et al*., 2008). Douglas and Munn (1992) described signature as the 'calling card' of an offender. "Signature is viewed as a highly individualized and unique combination of habitual aspects of offending behaviour derived from the fantasy and motive for a series of crimes perpetrated by a single offender" (Hazelwood & Warren, 2003 p. 597). As a result of the unique internal fantasies of offenders, offenders will respond in stable yet distinctive and unique ways when responding and reacting to situations (Hazelwood & Warren, 2003). Not only is signature helpful to investigators in gaining insight into the psychological motivations or personality traits of the offender, it also serves as an insight into interview strategies for investigators to utilise once the offender/suspect is in custody (Van der Watt *et al*., 2014).

Signature is highly relevant to crime linkage, as the signature of the offender does not change and is therefore, consistent (Keppel & Birnes, 2018). This is unlike the offender's MO which may evolve and change over time as the offender becomes more efficient and experienced at committing their offences or is impacted by situational influences such as substances or the mood of the offender (Crabbé *et al*., 2008; Hodgskiss, 2004; Pistorius, 2018). However, Gee and Belofastov (2015) suggest that although the sexual fantasy is static, complexity can emerge. In addition, the signature of an offender may be difficult to detect at a crime scene (Pistorius, 2018).

Pistorius (2018) stated that signature is not only expressed as a physical representation or behaviour, but it can also be a verbal expression or 'scripts' for the victims to say. As a result, the behaviours related to the signature of the offender may be absent or not apparent to investigators at the crime scene (Salfati, 2019). The reason why this is important to consider, is that investigators may often find crime scenes in the way the offender intends for others to find it, thereby eliminating behaviours which may indicate or suggest actual crime scene behaviours (Turvey, 2012a). This is often the case in linking crimes such as serial sexual murders, as there is often limited forensic and observed sexual activity at crime scenes (Bateman & Salfati, 2007; Salfati, 2019). Lack of observable sexual activity may be as a result of an offender deliberately removing evidence from the crime scene, using avoidance and detection strategies (Reale *et al*., 2020). However, certain environments may naturally degrade evidence, as in the case of serial murder offenders in South Africa, with victim's often being disposed of in isolated, outdoor environments which reduce physical and forensic evidence due to animal activity (scavenging) and the hot climate. Therefore, it is important to consider the natural environment and the geographical and spatial patterns of crimes to link crimes (Labuschagne, 2015b).

2.4.1.5 Spatial Patterns and Crime Proximity

When examining the behaviour consistency of spatial patterns of offenders, the term *geographic profiling* was developed in the 1970s relating to a process of locating an offender's likely residence by analysing the spatial patterns of serial offences crime scenes (Bennell *et al*., 2007; Berezowski *et al*., 2023; Canter & Larkin, 1993; Snook *et al*., 2004; Snook *et al*., 2005b). Geographic profiling is not only useful in determining whether a crime is committed by the same offender and locating the approximate residence of the offender, but also beneficial at linking crimes, locating clandestine graves or body recovery locations, bringing a sense of closure to victims' families, and possible identification of additional victims (Berezowski *et al*., 2023; Canter *et al*., 2017; Rossmo, 2019; Rossmo & Summers, 2015).

Canter and Larkin (1993) developed the term *Circle Theory of Environmental Range* (CTER), which predicts an offender's residence utilising the geographical locations of the known crime scenes of linked crimes. The *criminal range* of an offender is referred to as the location of the offender's residence, and the location of the crime (Ackerman & Rossmo,

2015; Rossmo, 2019; Rossmo & Summers, 2015). Tonkin *et al*. (2011) found that violent offenders had the shortest median distance of committing their crime in relation to their residence in comparison to property crime. This is reportedly due to a sense of familiarity, comfort, and control which an offender is likely to have when committing their crimes (Reale *et al*., 2021). Berezowski *et al*. (2023) reported that serial murder offenders tend to have a criminal range of between nine and 40 kilometres in which they commit their crimes. However, according to Berezowski *et al*. (2023), while an offender may control the geographic and environmental factors; due to their victim choice and selection, the victim inadvertently establishes the temporal and spatial factors. Therefore, the offender takes into consideration the relevant risk factors, and target selection behaviours into account when committing their crimes in geographic comfort zones (Berezowski *et al*., 2023; Canter *et al*., 2017; Curtis-Ham *et al*., 2021).

International research studies have found that serial murder offenders tend to have 'geographic comfort zones' in which they either approach their victims and/or commit the murders (Canter & Larkin, 1993; Labuschagne, 2021a; Snook *et al*., 2004; Snook *et al*., 2005a). Locations which are familiar to an offender are often targeted as the offender has prior knowledge of escape routes, enabling the offender to reduce and mitigate risk of being caught (Deakin *et al*., 2007; Nee, 2015; Reale *et al*., 2020; Reale *et al*., 2021). Corresponding with international research findings, geographic comfort zones of South African serial murder offenders was supported by findings of Collaros (2019) who, in her unpublished Doctoral study, found that the serial offenders (n = 15) whom she interviewed used a route-following model of environmental learning (Collaros, 2019). Examples of some South African serial murderers who committed their series in geographic comfort zones are; the *Brighton Beach axe serial murderer*, Phindile Ntshongwana; Richard Nyauza the *Quarry serial murderer* and, Sipho Twala the *Phoenix sugarcane serial murderer* (Labuschagne, 2021; Pistorius, 2018). As a result, geographic locations, temporal, and spatial proximity appear to be useful at linking and connecting crimes (Berezowski *et al*., 2023; Tonkin *et al*., 2011).

2.4.2 The Importance of Crime Linkage

There are several benefits to crime linkage, for example, the ability to effectively pool police resources to form a proactive rather than reactive investigation style and approach

(Woodhams *et al*., 2008). Not only is serial murder costly in terms of human life, but the law enforcement resources involved in serial investigations are also costly (Alison *et al*., 2002; Grubin *et al*., 2001; Woodhams & Toye, 2007). In addition, the analysis of forensic evidence, if available, is both costly as well as time consuming (Woodhams & Davies, 2021). Therefore, it is imperative that these types of offenders are apprehended as quickly and as efficiently as possible (Woodhams & Davies, 2021). According to Yaksic (2023), serial offenders are not a more sophisticated type of offender with mysterious and elite abilities, as often speculated and presumed. However, they do appear to display greater forensic awareness in comparison to once-off offenders (Chan *et al*., 2015; McKinley & Petherick, 2021). However, Yaksic (2023) postulates that serial offenders often rely on 'luck' to evade apprehension, as well as poor police work such as *linkage blindness*. Poor police work may also be due to substandard investigations as a result of lack of resources and/or ineffective communication between various departments (Bennell *et al*., 2012; Egger, 2002).

In addition, the standard method of practice for linking crimes through forensic evidence, such as DNA, ballistic, and fingerprint analysis, and results from post-mortem autopsies, may not be available at the crime scene, or if it is available, results and findings may take months to become available to investigators or prosecutors (Davies & Woodhams, 2019; Labuschagne, 2012). As a result, being proactive during the investigation stage and being able to detect potentially linked crimes based on crime scene behaviour, is not only important, but also a necessity (Salfati, *et al*., 2015). Resources can then be utilised to identify a minority of crimes or murders which are suspected of being committed by the same offender (Davies & Woodhams, 2019).

Therefore, crime linkage is predominantly used to identify whether one or more crimes are committed by a single offender and provides investigators in different precincts/districts a better focus for their investigations (Labuschagne, 2012). It is also used as similar fact evidence in legal and court proceedings, where forensic evidence may be incomplete or lacking (Horning *et al*., 2015; Labuschagne, 2015b). Crime linkage is not only useful in pooling law enforcement resources effectively in the detection of linked crimes and apprehension of the offender, but it is also a way to limit further victimisation and number of future victims (Woodhams & Davies, 2021). Furthermore, it may be able to provide surviving victims and the families of victims a measure of closure (Slater *et al*., 2015). For example, forensic evidence may not be available to link an offender to a particular crime.

However, through linkage analysis derived from the behavioural evidence available at the crime scene, it is determined that the same offender is responsible for the crime (Labuschagne, 2015a; Labuschagne, 2015b). This allows victims' families to see justice being served despite the lack of forensic evidence (Davies & Woodhams, 2019). Crime linkage is used to inform decisions during operational and legal processes (Winter *et al*., 2013), which will be discussed further below.

2.4.2.1 The Investigative Phase

In terms of investigations, crime linkage assists investigators in determining which crimes are likely to have been committed by the same offender (Labuschagne, 2012). Labuschagne (2015) states that crime linkage analysis should be continuously updated as new evidence becomes available, and particularly while waiting for results from laboratories which can take months. In such cases, crime linkage is particularly useful when forensic evidence may be lacking in some of the cases in a crime series (Davies *et al*., 2019; Labuschagne, 2012). During the initial stages, behavioural commonalities may be identified. According to Grubin *et al*. (2001), for consistency among crimes to be reliable and not merely coincidental, certain techniques are required for any successful case comparison. These techniques include a) the identification of relevant features of an offence, b) based on these identified features, a valid procedure to compare and determine the degree of similarity between them, and c) a means and way to calculate whether any similarity is more than a random event or merely coincidental (Grubin *et al*., 2001).

Crime linkage aids and assists investigators in determining which crimes should be included or excluded in a series, as well as to assist them in deciding how to focus their investigations in examining crimes which have been committed similarly in terms of crime scene behaviour (Labuschagne, 2012). Turvey (2012b) refers to this as the *investigative link* and allows for the allocation of additional investigative resources. In other words, by identifying a murder being part of a murder series, the strategy of investigation may change, task teams can be activated, experts can be consulted, and communication with the public on safety notifications regarding victim and geographical targeting information can be disseminated (Petherick *et al*., 2022). Further analysis may find that there are unique behaviours, with limited behavioural dissimilarity, shared across two or more cases which Turvey (2012b) refers to as a *probative link.*

Crime linkage also allows resources to be allocated and used effectively, as investigators are aware of where they need to focus their attention and resources (Labuschagne, 2012). Additionally, investigators may be able to determine which cases should be included or excluded in a series, based on crime scene behaviours (Davidson & Petherick, 2021). South Africa suffers from a backlog and overburden of the system in terms of DNA and forensic analysis (Machisa *et al*., 2023; Parliament of South Africa, 2025). Therefore, despite not having forensic evidence speedily available, it is still imperative to identify the behavioural elements of the crime scene (Van der Watt *et al*., 2014)

Criminal profiling has the added benefit of potentially being able to prevent future crimes being committed by the same offender by identifying the possible location/s, and/or time of a potential crime committed by the same offender, thereby reducing future potential victims (Hazelwood & Warren, 2003; Salfati, 2019). However, incorrect linkage made can be a waste of state resources (Labuschagne, 2006). Crime linkage can potentially reduce further future victimisation of an offender by linking an individual/s to a series which may lack forensic evidence thereby assisting in the aggravation of sentencing an offender with greater criminal propensity (Chai *et al*., 2024; Labuschagne, 2012). Not only is crime linkage beneficial to investigators, as it assists by organising and condensing large amounts of information into a concise framework, but it can also inform efforts to potentially link a series of crimes in the legal process which will now be briefly presented (Hazelwood & Warren, 2003; Woodhams & Labuschagne, 2012a).

2.4.2.2 The Trial Phase

Crime linkage is beneficial in legal proceedings as it can be presented as evidence in court to demonstrate when a single offender is responsible for a series of crimes (Labuschagne, 2015a). Grubin *et al*. (2001) report that when examining crime scene similarities, the frequency of a behaviour is important to consider in order to determine whether a particular behaviour occurred by chance or by coincidence. When a crime demonstrates highly unique and consistent behaviours, it can be termed a *substantial link* (Turvey, 2012b). Crime linkage has been used to assist decision making in courts, such as in convicting an offender (Davies *et al*., 2019; Hazelwood & Warren, 2003; Labuschagne, 2012). For example, if an offender is linked to multiple crimes, the court may find this to be an aggravating factor used when sentencing the offender, as the offender may pose a higher risk of reoffending (Petherick *et*

al., 2022). Therefore, crime linkage is used to strengthen the case against an offender, protecting society at large (Porter, 2014). Furthermore, crime linkage may also be a means to exclude certain cases or clear a suspect accused of committing a crime (Porter, 2014).

Crime linkage has been used successfully in South African legal contexts by providing similar fact evidence in court by linking crimes based on similar, yet unique, crime scene behaviours (Labuschagne, 2012; 2015). For example, the following cases have been linked through behavioural evidence in South Africa by providing similar fact evidence which was accepted by the courts: the *Quarry serial murderer* (State v. Nyauza, 2007); the *Knysna serial murderer* (State v. van Rooyen, 2007); and the *Newcastle serial murderer* (State v. Sukude 2006). Using human judgement (deductive, idiographic approach), linkage analysis is a reactive process which involves the following five stages used by practitioners and clinicians to provide an expert opinion on whether cases can be considered linked (Labuschagne, 2012). Although each stage is distinct, they are inter-related activities (Hazelwood & Warren, 2003; Labuschagne, 2012):

i) Obtaining all documentation relevant to the case.
ii) Establishing the noteworthy crime scene behaviours.
iii) Review and classify all MO and ritualistic behaviours.
iv) Determining whether there is a unique or unusual behaviour, or sets of behaviours (the offender's signature), across each crime scene.
v) Compiling a written report to investigators or prosecutors with the above-mentioned analysis.

Using this process, the psychologist working for the IPS were able to effectively demonstrate to the courts that the crimes were committed by the same offender based on consistent yet unique behaviours (Labuschagne, 2015b). Information used to link cases were crime scene and autopsy photographs, sworn statements, medic-legal autopsy reports and laboratory reports, visiting the crime scenes (post-fact), consulting with the investigator officer, considering and identifying MO behaviours, signature, and ritual behaviours, as well as taking geographic and spatial factors into consideration (Labuschagne, 2012). However, while the expert opinion regarding linkage analysis was considered in South African courts under the legal principle of similar fact evidence and expert evidence (Labuschagne, 2015a), there are various legal standards and sets of principles which need to be met in other countries**,** such as the USA (Tonkin & Weeks, 2021). In the USA these standards are referred to as the *Daubert (1993) Standards.* Daubert standards are the judicial set of principles used

by courts to determine whether evidence is deemed reliable and admissible to the court regarding the methodologies used, ensuring that they have been based on sound scientific principles (Davies *et al*., 2019; Pakkanen *et al*., 2015a). Pakkanen *et al*. (2015a) list the following six standards and principles which evidence needs to meet in order to be considered admissible to the court:

1. *Reliability* of the methods used.
2. The methodology has been *published* after undergoing *peer review*.
3. *Error rates* have been established.
4. There is *general acceptance* among the scientific community regarding the validity and reliability of the method.
5. *Standards* of practice are met.
6. *Applicability* of the case (fit) to the methodology used.

In some countries, crime linkage has not been ruled as admissible in court due to criticism regarding the reliability and validity of methods and samples used (Pakkanen *et al*., 2015a; Woodhams *et al*., 2019). As a result of these serious implications and in order to enhance the practical applicability of crime linkage, it is important that crime linkage research using valid, empirically based samples, is conducted to inform evidence-based practice (Davies & Woodhams, 2019). Some of the approaches, methods, and empirically based studies will now be discussed.

2.4.3 Crime Linkage Research

Crime linkage research studies have been conducted on a range of offence types including: arson (Ellingwood *et al*., 2013); commercial robbery (Woodhams & Toye, 2007); commercial burglary (Bennell & Canter, 2002; Bennell & Jones, 2005); residential burglary (Melnyk *et al*., 2011; Tonkin *et al*., 2019; Tonkin *et al*., 2012a); personal robbery (Burrell, 2022; Burrell *et al*., 2012); serial murder (Melnyk *et al*., 2011; Pakkanen *et al*., 2021); sexual offences (Bennell *et al*., 2021; Davidson & Petherick, 2021; Grubin *et al*., 2001; Winter *et al*., 2013; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a); and across different crime types (Tonkin *et al*., 2012b).

Fox and Farrington (2018) conducted a meta-analysis of crime linkage studies produced between 2002 and 2016. They found that of the studies related to criminal profiling, crime

linkage studies had the highest level of scientific quality as indicated by an overall AUC of .83 (95% CI = .76 - .89), which is considered excellent (Fox & Farrington, 2018). The AUC indicates the overall level of predictive accuracy, with values closer to one (1) indicating perfect discrimination ability for the model to correctly predict outcomes, while values less than .50 suggest that the model performs worse than chance (Bennell & Canter, 2002). This suggests that crime linkage is successful at linking crimes committed by the same offender based on similar yet distinctive crime scene behaviours (Fox & Farrington, 2018). Since then, research on the theory of crime linkage has increased over the past decade by using ecological valid samples and data which closely reflect naturalistic police investigations and settings (Davies & Woodhams, 2019). According to Bennell *et al*. (2015), there are three main levels of analysis used to crime linkage namely: the domain approach, the MO approach and, the thematic approach (Bennell *et al*., 2015; Tonkin, 2015). Which approach is chosen and the subsequent methodology utilised, will depend on the researcher, with regard to the sample and what the focus and purpose is of the study.

Linking crimes through the *MO approach* is usually conducted by analysing all the individual and idiosyncratic behaviours of the crime scene (Porter, 2014). Methods to determine the accuracy of MO behaviours to link crimes are Bayesian modelling, MO-based clustering procedures, general algorithmic approaches, and similarity coefficients (Bennell *et al*., 2015). In Fox and Farrington's (2018) meta-analysis of the 34 crime linkage studies (n = 34), outstanding levels of linking accuracy were found to be higher for interpersonal crimes such as serial murder (n = 1; AUC = 0.96), across crime types (which included sexual crimes) (n = 2; AUC = 0.90), and serial sexual offences (n = 8; AUC = 0.86) as indicated by the AUC values. Whereas property related crimes displayed lower, yet still acceptable levels of discrimination accuracy for car theft (n = 7; AUC = 0.72), burglary (n = 11; AUC = 0.73), and robbery (n = 5, AUC = 0.84) (Fox & Farrington *et al*., 2018).

Analysing all crime scene MO behaviours is helpful as it provides the overall consistency of offending behaviour, rather than focusing on individual or specific behaviours or groups of behaviour considering that the variability of an offender's behaviour may be due to interaction with the victim and situational contexts (Woodhams *et al*., 2019). Originally, MO was thought to be stable however, as an offender gains experience due to maturity or learning and situational factors such as the interaction with the victim, the MO may change and/or evolve over time (Hazelwood & Warren, 2003), consistent with the learning hypothesis

(Canter & Youngs, 2003). As a result, researchers determined that examining behaviours under psychological themes may be more useful at linking crime, as the interaction with the victim and offender can then also be considered (Bennell *et al*., 2009; Bennell & Canter, 2002).

The *thematic approach* categorises the cases into different themes and then measures and determines whether crimes in the series exhibit the same theme or not (Davies & Woodhams, 2019). Sorochinski and Salfati (2010) suggested that, instead of examining individual and idiosyncratic behaviours, behavioural patterns as well as patterns of change should be explored. According to Bennell *et al*. (2015), the basis of grouping behaviours based on the thematic approach are empirically driven. The themes are derived from statistics which use clustering procedures and related to psychologically meaningful themes (Bennell *et al*., 2015). Statistical methods used to test the thematic approach are *multidimensional scaling, principal component analysis*, and *cluster analysis* (Bennell *et al*., 2015). Crime linkage studies have indicated that there are higher levels of consistency for behaviours which are considered within the control of the offender such as planning behaviours, which are less situation-dependent (Bennell & Canter, 2002; Tonkin *et al*., 2019). However, behaviours which are impacted by the interaction with the victim (Canter, 2004; Morton & McNamara, 2005), and less in the control of the offender, were found to be less consistent across crimes (Davies *et al*., 2018; Woodhams & Toye, 2007).

According to Bennell *et al*. (2015), the *functional domain approach* is the balance between the MO approach and the thematic approach. MO behaviours are examined but are grouped into certain domains based on their assumed function (Tonkin *et al*., 2012a). Statistical methods commonly used for the analysis of the functional domain approach are *logistic regression analysis* (Bennell *et al*., 2015) and *classification tree analysis* (Tonkin *et al*., 2012c). Bennell and Canter (2002) argue that different domains of MO behaviour set out in terms of their functionality, may assist in identifying which functional domains prove to be more useful and accurate for the purpose of crime linkage, and which functional domains are less helpful and effective at linking crimes (Bennell & Canter, 2002). Using all MO behaviours was found to be more accurate when analysing interpersonal crimes such as murder and sexual assaults (Bennell *et al*., 2010; Melnyk *et al*., 2011; Woodhams & Labuschagne, 2012a;), while spatial and temporal factors were found more useful for property related serial crime**,** such as robbery and burglary (Burrell *et al*., 2024; Tonkin &

Woodhams, 2017). To date, however, no study has examined serial murder offenders using the functional domain approach. According to Salfati (2019), only four empirical studies have examined linking crimes based on the behaviour consistency of serial murder offenders using psychological themes. These are discussed below.

2.4.3.1 Empirical Studies Linking Serial Murder Based on Behaviour Consistencies

In one of the first studies to quantify behaviour consistency, Salfati and Bateman (2005) studied serial murderers (n = 23) in the USA to determine whether they could successfully categorise serial murder offenders' behaviours into *expressive* and *instrumental* themes from 69 murders. Salfati and Bateman (2005) suggested that there are benefits in shifting focus from individual features to themes of behaviour, as themes of behaviour would be able to factor in behavioural changes due to the interaction with the victim or change in situation/s. Although they found consistency in theme dominance in 13-16% of the series, the levels of consistency were low. They suggested that further research should be done in order to determine which variables are impacted by the interaction with the victim and/or situational factors and remove them from the themes (Salfati & Bateman, 2005). Santtila, (2008) however, stated that the themes are too general, and the model lacks testing the predictive accuracy of determining whether they will be useful at differentiating between offenders.

Shortly after, Bateman and Salfati (2007) were the first study to examine whether individual signature behaviours or subgroups are more useful at linking crimes. They found that behaviours which were the most common (high frequency behaviours) in a series were also high frequency behaviours across series and therefore, were not useful at differentiating between offenders (Bateman & Salfati, 2007). As a result, only five out of the 35 behaviours were identified to be highly consistent across crimes but were unique enough at distinguishing them from other series (Bateman & Salfati, 2007). Therefore, they suggested focusing on shifting to theme-based and type-based crime scene behaviour/s, as they found low levels of consistency when focusing on individual and isolated features of crime scene behaviour. Bateman and Salfati (2007) identified six groups of behaviours related to the literature on signature behaviours of serial murderers, which included sexual behaviours, body disposal behaviours, forensic awareness behaviours, theft, mutilation, and weapons used. The results indicated that behaviours related to planning and control were the most

consistent and useful at linking crimes, although behavioural consistency was still low (Bateman & Salfati, 2007). They further highlighted findings from previous research which suggested that behaviours which are outside the offender's control are influenced by situational characteristics, which is why factors which are within the offender's control are more consistent across crimes (Bennell & Canter, 2002; Salfati & Bateman, 2005). Bateman and Salfati (2007) found the sexual component of serial murder offenders to be the least consistent and reliable for linking crimes. This highlights that not all serial murder offenders are sexually motivated, and that observable evidence of sexual activity is often non-existent or unavailable at the crime scene (Salfati, 2019).

Sorochinski and Salfati (2010) later examined the behaviour consistency of 19 murder series (n = 19) in the USA by exploring three different themes of behaviour namely: planning (pre and post), wounding (goal directed and process oriented), and offender-victim interaction (victim as vehicle, person, and object). Regarding planning, 42.1% were found to be consistent in using the same pre and post planning strategy theme. Notably, most of the changes were found between the first and second offence, and therefore, were considered a transition and learning process (Canter & Youngs, 2003; Salfati, 2015). Few offenders were found to be consistent with regard to wounding behaviours as only 31.5% displayed thematic consistency, replicating findings from Salfati and Bateman (2005) study. Sorochinski and Salfati (2010) suggested that this was as a result of the interaction of the victim, and that changes in behaviour were attributed to cognitive strategies used to respond to situational and contextual influences (such as the reaction and resistance from the victim), and as a result, may have been 'victim specific' (Mischel & Shoda, 1995; Salfati, 2015; Sorochinski & Salfati, 2010). In addition, victim interaction appeared to display the most consistency, particularly *victim as vehicle* theme which was consistent among 57.9% of the series. This study demonstrated the consistency of inconsistent behavioural patterns of serial murder offenders over the course of their series (Sorochinski & Salfati, 2010). This highlighted important considerations in understanding behaviour variability among offenders, and why it is important to include all victims within a series for the purposes of crime linkage research (Salfati, 2019).

Within the South African context, Salafti *et al*. (2015) conducted a similar approach to Sorochinski and Salfati (2010) by exploring the planning, wounding, and victim interaction behaviour consistency of 30 serial murderers in South Africa who had a total of 283 victims.

Salfati *et al*. (2015a) combined the findings from Horning *et al*. (2015) who examined victim-interaction (victim as person, vehicle, and object), and Sorochinski *et al*. (2015) who examined violence (goal directed and process oriented), and planning (pre and post) behaviours, to determine consistency of themes as a series progressed. Salfati *et al*. (2015a) found that *victim as vehicle* was the more dominant theme among victim type interaction, using victims as 'a means to an end'. However, as series progressed consistency decreased, suggesting victim resistance and/or situational influences which impacted the behavioural response of the offender (Salfati *et al*., 2015a). While lower levels of consistency were found for *victim as object*, the theme remained consistent across crime. This suggests that the interaction with the victim is useful for classification purposes as behaviours displayed may be specific to the victim, corresponding with findings from Sorochinski and Salfati (2010) study.

Interestingly, although most offenders target vulnerable victim as the beginning if their series, they changed patterns as series progressed, which Salfati (2019) interprets as the offender gaining confidence at not being apprehended, and thus taking more risks. Levels of violence displayed the lowest levels of consistency (37%) across crimes, consistent with Sorochinski and Salfati (2010) study. The majority of offenders changed wounding patterns between the first and second offence, indicating that the response from the victim impacts the type of wounding behaviours used (Salfati *et al*., 2015a). In terms of planning, most South African serial murderers engaged in pre-planning their offences, with little post-planning. This is understood to be as a result of the low socioeconomic status of serial murder offenders in South Africa, who are often on foot and cannot transport victim's bodies (Sorochinski *et al*., 2015). Therefore, they plan their crimes in advance and choose crime scene body disposal sites which will naturally conceal their crimes and destroy forensic evidence. These preselected body disposal sites are often in hot, outdoor, and secluded locations which serve as natural post offence strategies to destroy evidence through natural degradation of crime scene evidence (Sorochinski *et al*., 2015). This means that South African offenders do post offence planning during the pre-planning stage (Salfati *et al*., 2015a; Sorochinski *et al*., 2015).

While these studies have been referred to as behavioural linking studies, Burrell *et al*. (2024) most recently stated that while these studies examined behaviour consistency, they lack providing a prediction of linked status of crimes. As a result, they lack examining

distinctiveness, one of the core assumptions of crime linkage. Burrell *et al*. (2024) therefore argue, that in order to examine the assumptions of crime linkage, both behaviour consistency as well the distinctiveness of an offender's behaviours need to be examined and determined using the steps in methodologies discussed below (Burrell *et al*., 2024). As a result of this, few serial murder studies have empirically tested the underlying assumptions of crime linkage by examining both behaviour consistency as well as distinctiveness of serial murder offenders (Pakkanen *et al*., 2021).

2.4.4 Methodologies Used to Test the Underlying Principles of Crime Linkage

Walklate (2013) posits that crime is viewed as an event rather than a process, and therefore, can be measured and quantified using statistical analysis. Burrell *et al*. (2024) state that while there may be different methodologies used to approach crime linkage, they all ultimately measure the i) similarity of crimes, ii) predict the linkage status, and iii) test the accuracy of these predictions. To further examine the different methodologies used in crime linkage research, Burrell *et al*. (2024) conducted a study to explore the most common methods used, by examining 77 crime linkage studies (n = 77). **Table 2.1** provides a summary of the methodologies used to achieve these measures according to Burrell *et al*., (2024). In order to meet the criteria to be included in the study, crime linkage studies had to test the behaviour consistency and distinctiveness of crime pairs by determining behaviour similarity, predicting linkage status, and measuring the accuracy of these predictions (Burrell *et al*., 2024).

To determine similarity of crimes, Jaccard's coefficients were found to be the most common, with 45% (n = 35) of the studies utilising this method. Using Jaccard's coefficient, studies have been able to successfully determine that linked crime pairs have significantly higher levels of behavioural similarity in comparison to unlinked crime pairs, providing support for one of the assumptions of crime linkage which is behaviour consistency and similarity across crimes (Bennell *et al*., 2021; Bennell & Canter, 2002; Davidson & Petherick, 2021; Melnyk *et al*., 2011; Pakkanen *et al*., 2021; Tonkin *et al*., 2012a; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a).

Table 2.1

Summary of Methodologies Used by Researchers to Test Crime Linkage.

	Measurement	Methodologies Used
i)	**To Preprocess Data and Determine Similarity of Crimes**	• **Human Judgement** (Labuschagne, 2006); • **Similarity metrics** (such as *Jaccard's similarity coefficients* and *taxonomy scales*) (Bennell *et al*., 2021; Melnyk *et al*., 2011; Pakkanen *et al*., 2021b; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a); • **Mokken Scales** (Santtila *et al*., 2008a); • **Temporal and spatial measures** (Borg & Boldt, 2016; Markson *et al*., 2010; Tonkin *et al*., 2011; Tonkin *et al*., 2012b).
ii)	**To Predict linked status and series membership**	• **Human judgement** using case files (Labuschagne & Salfati, 2015); • **Statistical methods** such as *logistic regression* and *multidimensional scaling* (Bennell *et al*., 2021; Bennell & Canter, 2002); • **Discriminant Function Analysis** (Santtila *et al*., 2008); • **Bayesian approaches** (Pakkanen *et al*., 2021; Salo *et al*., 2013); • **Iterative Classification Trees** (Bennell *et al*., 2021).
iii)	**To Determine the accuracy of linked predictions**	• **Hit rates** (Santtila *et al*., 2008); • Position on a **ranked list** (Porter, 2014); • **ROC** and **AUC values** (Bennell *et al*., 2021; Bennell & Canter, 2002; Burrell, 2022; Davies *et al*., 2019; Melnyk *et al*., 2011; Pakkanen *et al*., 2021; Woodhams & Labuschagne, 2012a).

To predict the linked status or series membership, logistic regression was found to be the most common, as 35% of the studies also used this method (Bennell *et al*., 2015; Bennell & Canter, 2002; Burrell *et al*., 2024). Logistic regression is used as it is considered to be one of the most widely understood statistical method to predict series membership (Bennell & Canter, 2002). To determine the accuracy of predictions, Burrell *et al*. (2024) found that 48% (n = 37) of the crime linkage studies used ROC and AUC to measure and assess the accuracy of linked predictions (Burrell *et al*., 2024).

ROC is a popular method in crime linkage research as researchers are able to determine and set various decision thresholds among a range of outcomes (Ewanation *et al*., 2023). ROC and accompanying AUC values provide relative measure of linking accuracy by indicating the percentage of times linked crime pairs will have higher probability scores than unlinked

crime pairs (Bennell & Canter, 2002; Ewanation *et al*., 2023). ROC with accompanying AUC values is considered the *gold standard* of crime linkage research (Bennell *et al*., 2015; Burrell *et al*., 2024; Ewanation *et al*., 2023). There are only two studies which have tested the principles of crime linkage empirically using a sample of serial murderers using the above-mentioned 'gold standard' methodology of crime linkage (namely using ROC and AUC).

Bennell *et al*. (2014) assessed levels of accuracy among fourteen (n = 14) crime linkage studies and found AUC values which ranged from 0.45 to 0.96. AUC values are interpreted using the following preestablished guidelines (Hosmer *et al*., 2013; Hosmer & Lemeshow, 2000): Outstanding (AUC ≥ .90); Excellent (.80 ≤ AUC ≤ .90); Acceptable (.70 ≤ AUC ≤ .80); and Ineffective (AUC ≤ .70). Within that range, 14% were within the outstanding range, 49% were within the excellent and acceptable ranges, and 36% were ineffective (Bennell *et al*., 2014) as demonstrated in **Figure 2.1** below.

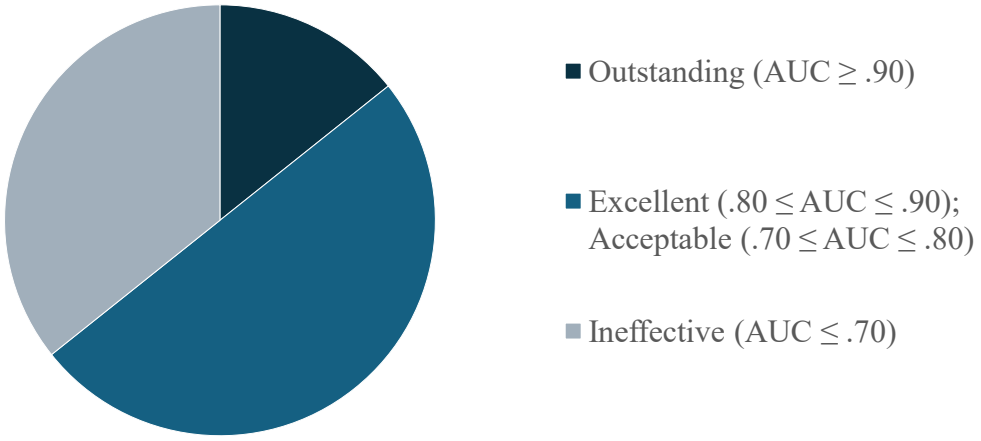


Figure 2.1 Accuracy of crime linkage studies examined by Bennell *et al*. (2014) according to AUC value Interpretation.

Serial murder studies which have empirically tested the underlying principles of crime linkage will now be presented in chronological order, including studies which have enhanced the ecological validity of crime linkage by addressing issues regarding sample bias. Although two of these studies are not related to serial murder, they are the first two studies to test the underlying principles of crime linkage using unsolved cases, which is important to present in relation to the aims and objectives of the current study (Woodhams *et al*., 2019).

2.4.5 Empirical Tests of Crime Linkage

The Santtila *et al*. (2008) study is perhaps one of the first studies to test the principles of crime linkage using serial murder cases by examining behaviour consistency and distinctiveness using a sample of solved serial murders in Italy (n = 23). Mokken scaling was used to determine similarity of crime, and discrimination function analysis to predict the series membership of 23 offenders. Five scales were found related to *motivation*, and two scales were related to *planning* behaviours. In relation to planning, forensic awareness was found in over half of the sample, suggesting that planning behaviours remain consistent, even though there may variability regarding the type of individual behaviour displayed. Sexual motivations were found in less than a third of their sample, once again highlighting that not all serial murderers are sexually motivated (Bateman & Salfati, 2007; Santtila *et al*., 2008). The LOOCV method was used to validate the results and predict the accuracy (Woodhams & Labuschagne, 2012a). The accuracy of linked predictions found a hit rate of 62.9%, which meant that almost 63% of the predictions were correctly assigned, while 6.2% could be expected due to chance (Santtila *et al*., 2008). The first limitation of this study is the ecological validity of the sample, as it only used a small number of solved serial murder cases (Davies & Woodhams, 2019). A second limitation is that it did not use original police case files (Pakkanen *et al*., 2021). These are considered limitations as it has been suggested that solved cases are behaviourally more unique and similar, which made them easier to link and therefore solve (Bennell & Jones, 2005). In addition, using original police case files would have enhanced mirroring naturalistic police settings and ensure the accuracy of the data (Pakkanen *et al*., 2021).

As stated previously, the first study to test the principles of crime linkage using the *gold standard* methodology of crime linkage using a sample of serial murder offenders was Melnyk *et al*. (2011) who examined all crime scene behaviours from 79 murder series with 237 victims. They coded 39 behaviours based on the organised and disorganised behaviour typologies, which included planning, control, and ritualistic behaviours. Jaccard's coefficient was used to determine similarity of crime pairs, and behaviour consistency was observed as linked crime pairs were significantly more similar than unlinked crime pairs (Melnyk *et al*., 2011). This finding is consistent with results from previous crime linkage research (Bennell & Canter, 2002). Logistic regression was used to predict series

membership, and the accuracy of linked prediction was tested using ROC to determine discrimination accuracy between linked and unlinked crime pairs (Melnyk *et al*., 2011).

The AUC was calculated to determine the specificity and sensitivity of the model's predictions to correctly classify crime pairs and resulted in an AUC of .96 (95% CI = .94 - .98) which is considered to be 'excellent' (Hosmer *et al*., 2013) at discriminating between linked and unlinked crime pairs (Melnyk *et al*., 2011). This suggests that serial murder offenders display consistent and similar behaviours across crimes yet are distinct enough to be able to discriminate and distinguish from other crimes committed by different offenders (Melnyk *et al*., 2011). It is important to report that the AUC value of .96 indicates that linked crime pairs will have higher similarity coefficient scores 96% of the time compared to randomly selected crime pairs committed by different offenders (Ewanation *et al*., 2023). Limitations of the study concerned the sample, as only solved serial cases were included (Pakkanen *et al*., 2021). This is seen as a limitation as it has been suggested that solved series were behaviourally similar yet unique, which is why they were easier to link, and therefore solve (Bennell & Jones, 2005). Furthermore, it has been argued that solved cases are not representative of what occurs in naturalistic settings, as investigators are faced with crimes committed by unknown perpetrators, without knowing if they are part of a series of crimes committed by the same individual/s (Woodhams & Labuschagne, 2012a).

To address one of the limitations of crime linkage research which have been criticised for only using solved series, Woodhams and Labuschagne (2012a) tested the principles of crime linkage among a sample of solved and unsolved (but linked forensically) serial sexual offenders. The sample consisted of 119 victims resulting from 22 serial sexual offenders (n = 22 series) in South Africa. The study used all MO crime scene behaviours and coded behaviours dichotomously to indicate presence (1) or missing/absence (0) of a crime scene behaviour (Bennell & Canter, 2002). Jaccard's similarity coefficient of crime pairs were calculated using B-LINK (Bennell & Canter, 2002). They found that offences which were committed by the same offender (linked crime pairs) displayed higher levels of behaviour similarity than offences which were committed by different offenders (unlinked crime pairs), based on the Jaccard's similarity coefficient scores (Woodhams & Labuschagne, 2012a). However, behavioural similarity for crime pairs that were linked first using MO (M = .51, SD = .11) revealed greater behavioural similarity in comparison to crimes which were first

linked through evidence such as DNA (M = .47, SD = .11), although the difference was small (Woodhams & Labuschagne, 2012a).

Thereafter, LOOCV was done to cross validate the data, before using logistic regression analysis with resulting ROC and AUC value to determine discrimination accuracy (Woodhams & Labuschagne, 2012a). Youden's index was calculated to determine the maximum number of correct linked cases (hits/sensitivity) with the corresponding lowest number of false alarms (1-specificity) (Bennell *et al*., 2009). This resulted in a Jaccard's coefficient value of 0.35 which produced the highest number of hits while reducing the number of false alarms (Woodhams & Labuschagne, 2012a). Low levels of behaviour similarity of linked crime pairs are similar to findings of research studies which also used Youden's index as a cut-off point (Davidson & Petherick, 2021). For example, the Bennell *et al*. (2009) study had a Jaccard's coefficient of 0.33 and a hit rate of 72%, Slater *et al*. (2015) had a Jaccard's coefficient of 0.24 with a hit rate of 79%, and Davidson and Petherick (2021) had a Jaccard's coefficient of 0.33 and a hit rate of 86.6%. This demonstrates that high levels of behavioural similarity are not necessary for linking crimes (Bennell *et al*., 2009).

Overall, however, Woodhams and Labuschagne (2012a) found that the model achieved 'excellent' levels of discrimination accuracy (AUC = .88, 95% CI = .86 - .90) when all crimes were considered. This provides further support for the assumption of crime linkage that crimes can be differentiated from one another (Bennell & Jones, 2002). Therefore, the study was able to successfully determine that crimes committed by the same offender displayed significantly more similar behaviours (suggesting behaviour consistency). In addition, crime pairs could also be differentiated from one another (indicating distinctiveness) with excellent discrimination accuracy (Woodhams & Labuschagne, 2012a). In addition, Woodhams and Labuschagne (2012a) conducted further analysis using two randomly selected crime pairs per offender to determine if prolific offenders overinflate linking accuracy which had previously been suggested (Bennell & Canter, 2002). However, the model still achieved significant and adequate levels of predictive accuracy (AUC = .77, 95% CI = .67 - .87). This finding was important for crime linkage research, as it demonstrates that prolific offenders do not obscure the data and inflate linkage accuracy in crime linkage research (Bennell & Canter, 2002). They did find however, that as series progressed, there was greater behaviour consistency in 77% of the cases (7/9), as indicated by similarity of

crime pairs MO behaviour from the first to the last crime pair. This also suggests that there is a process of learning and experience which takes place (Woodhams & Labuschagne, 2012a). Limitations of the study was the small sample size (n = 22), and only including serial offences (Woodhams *et al*., 2019).

Salo *et al*. (2013) extended the Santtila *et al*. (2008) study and examined all crime scene behaviours of 19 serial murder offenders (n = 19 series) in Italy who had a total of 116 cases, all of which were solved. They coded 92 variables dichotomously to presence (1) or absence (0) of crime scene behaviour and used a Bayesian approach to determined series membership (Salo *et al*., 2013). To assess the prediction accuracy, the LOOCV method was used (Woodhams & Labuschagne, 2012a). The study found that when examining all 92 behaviours, the model achieved a classification accuracy of 83.6%, which was significantly higher than what could be expected by levels of chance, which was 5.3% (Salo *et al*., 2013). Interestingly, they found that the same level of predictive accuracy (83%) was achieved when the model was reduced to only 15 variables. Similar limitations to the Santtila *et al*. (2008) study were found regarding the sample size, only using solved series, and not using original police case files (Pakkanen *et al*., 2021). This was the first study to use a sample of serial murder offenders using the Bayesian model, which is becoming increasingly more popular in crime linkage research as it is known to be more practitioner-orientated (Burrell *et al*., 2024).

To address the limitations of crime linkage studies which have been criticised for having small, solved, and serial samples, and to further enhance ecological validity of crime linkage, Woodhams *et al*. (2019) conducted what is to be considered the largest international and ecologically valid crime linkage research of sexual crimes using all MO behaviours. Their study included 668 serial sexual offences and 92 unsolved cases (which were linked forensically through DNA). Data were collected from five countries, including South Africa, and Cohen's kappa was used to establish interrater reliability within datasets and to reduce coding bias (Woodhams *et al*., 2019). Jaccard's coefficient was used to assess similarity of crime pairs which determined that linked crime pairs were significantly larger than unlinked crime pairs, confirming behaviour consistency of offenders (Woodhams *et al*, 2019). However, variability of offending behaviour was found as indicated by minimum and maximum Jaccard's coefficient scores, which is consistent with previous studies (Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a).

Woodhams *et al*. (2019) used logistic regression to predict the linked status of crime pairs before using the LOOCV method to validate the results, as done in previous studies (Tonkin *et al*., 2012a; Woodhams & Labuschagne, 2012a). To test the relative accuracy of linked predictions, discrimination accuracy of crime pairs was assessed using ROC and AUC, as done in previous crime linkage research (Bennell & Canter, 2002; Tonkin *et al*., 2012a; Woodhams & Labuschagne, 2012a). Linked crime pairs were significantly different compared to unlinked crime pairs for solved as well as unsolved crimes. In addition, excellent discrimination accuracy was found for solved crimes (AUC = .86, 95% CI = .86 - .87) and, although the predictive model still achieved acceptable levels of discrimination accuracy (Hosmer *et al*., 2013) for unsolved crimes, the AUC decreased slightly to .79 (95% CI = .77 - .81). Overall, the model achieved excellent discrimination accuracy when both solved and unsolved series were included with an AUC of .86 ($p < .001$, SE = .003, 95% CI = .86 - .87). After consulting with practitioners regarding the decision threshold which would be most useful in practice, Woodhams *et al*. (2019) implemented a 15% false alarm rate which still resulted in a very large number of incorrect linkages made (over 500 000). This suggests that different offenders (unlinked crime pairs) may display high levels of behaviour consistency, and that the same offender (linked crimes pairs) may display inconsistent behaviours. In other words, this highlights the variability in offending behaviour and that the principles of crime linkage are not applicable or true for all offenders (Woodhams *et al*., 2019).

In a more recent study of serial murder which tested the underlying principles of crime linkage, and to address criticisms of previous crime linkage research studies for only including serial offences, Pakkanen *et al*. (2021) conducted a study using serial murderers and once-off 'hard to solve' solved murders in Italy. The sample consisted of 23 serial murder offenders (n = 23 series) which had a total of 116 murder victims, and 45 once-off murder victims. Data were collected from media reports such as newspaper articles, journals in libraries, and internet searches**.** Eighty-nine variables were coded dichotomously from all MO behaviours to indicate presence (1) or absence (0) of a crime scene behaviour. Using Jaccard's similarity coefficient and the Bayesian method, as done in the Salo *et al*. (2013) study, linked crime pairs of serial murder offenders had higher probability values of being linked than once-off murders. Despite Pakkanen *et al*. (2021) predictions for their study, the overall level of accuracy, as determined by the AUC value, increased from .88 (95% CI = .81 - .93) when only serial murderers were included, to .90 (95% CI = .81 - .94); when all

once-off and all serial offences were included, despite an initial decrease to .85 (95% CI = .76 - .91); and when 30 once-off cases were added to the sample (Pakkanen *et al*., 2021). This means that serial murder offenders were able to be differentiated from once-off offenders, supporting previous findings of serial murder research (Chan *et al*., 2015; Pakkanen *et al*., 2015b). As a result, this finding suggests that serial murder offenders can be considered a heterogenous group (Pakkanen *et al*., 2021).

Using one decision threshold, Pakkanen *et al*. (2021) used Youden's index (as done in Bennell & Jones, 2005; Slater *et al*., 2015; Tonkin *et al*., 2011) to maximise the number of hits, while reducing the number of false alarms. However, although there was an increase in the sensitivity to identify correct series, they did find that there was an increase in false positives in linked decisions, which indicated decreased specificity (Pakkanen *et al*., 2021). This has implications for court proceedings as this could result in a false conviction as a case may be incorrectly identified as being positively linked in a murder series, where in fact the crime is not linked (Pakkanen *et al*., 2021). Ewanation *et al*. (2023) posit that existing crime linkage research, such as the Pakkanen *et al*. (2021) study, limit the application of crime linkage as they have only applied and reported on one decision threshold. This is considered a limitation as different types of error rates and false alarms will be acceptable and necessary during different phases of the investigative and trial stages (Ewanation *et al*., 2023). Therefore, Ewanation *et al*. (2023) have suggested that future crime linkage research should apply a range of decision thresholds, demonstrating and reporting on the different performance outcomes which are necessary and applicable during different stages of the investigation.

Therefore, while the Pakkanen *et al*. (2021) study is one of the few studies examining crime linkage among serial murder offenders, and the first to compare and test the principles of crime linkage between serial and once-off murders, it lacks ecological validity in other aspects which could be considered limitations. For example, it only included solved crimes, and did not use original police case files, reflecting natural investigative settings (Woodhams & Labuschagne, 2012a; Woodhams *et al*., 2019). In addition, Pakkanen *et al*. (2021) did state that their findings may have been because of cultural implications due to mafia related murders, and therefore, the generalisability of their findings to other countries is likely limited.

2.4.6 Difficulties and Limitations of Crime Linkage

2.4.6.1 Practical Limitations

From a practical and investigative perspective, Keppel (1995) stated that contamination of crime scenes affects crime linkage. Contamination of a crime scene include environmental factors such as the weather and animal activity, which is a particularly relevant limitation in the South African context (Sorochinski *et al*., 2015). Due to body disposal location sites being in secluded, outdoor locations, the environment in which serial murder offenders operate naturally degrades forensic evidence as a result of animal activity such as scavenging, and increased body decomposition due to high temperatures of the natural climate in South Africa (Sorochinski *et al*., 2015).

In addition, poor crime scene analysis or investigations, and limited knowledge regarding the identification and linking of crime scene behaviours further compound the issue (Labuschagne, 2015b) which Egger (1984) refers to as *linkage blindness*. Linkage blindness is essentially the inability to link together crimes committed by the same person (Egger, 1984). There are several possible reasons for this failure, including ineffective police investigations, poor investigation strategies, lack of communications between law enforcement agencies, forensic databases not being connected, and lack of knowledge or training, to name a few (Egger, 1984; Yaksic, 2023). Additionally, investigators may be overworked and dealing with a large number of cases at one time, as is the case in South Africa, and investigators may lack knowledge of how to identify nuanced crime scene behaviours (Van der Watt *et al*., 2014).

Variability in offending behaviour contributes to the challenge of correctly linking crimes, and incorrectly connecting crimes can result in wrongful convictions (Sorochinski *et al*., 2023; Woodhams *et al*., 2019). In addition, the accuracy of crime linkage is going to be impacted by the quality of the data and where it is obtained from (Bennell *et al*., 2021). If the quality of the investigation and documentation of the crime scene is poor, this will impact on the quality and accuracy of being able to link crimes (Bennell *et al*., 2021; Ewanation *et al*., 2023). This can result in the offender not being apprehended, incorrect arrests being made, cases not being linked, and cases being withdrawn from prosecution. Incorrectly linking crimes is a waste of (often limited) state resources (Labuschagne, 2006). SAPS has been accused of linkage blindness in some of their investigations in serial rape cases (Van

der Watt *et al*., 2014). For example, a serial rapist was active in a small geographical area using the same and consistent MO, yet police investigators reportedly made no effort, and failed, to connect, and link these cases (Van der Watt *et al*., 2014).

2.4.6.2 Limitations of Previous Crime Linkage Research

A criticism of crime linkage is its lack of ecological validity and the generalisability of the findings of previous research (Bennell *et al*., 2021; Davidson & Petherick, 2021; Ewanation *et al*., 2023; Pakkanen *et al*., 2021; Tonkin *et al*., 2012b; Winter *et al*., 2013; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). Woodhams and Labuschagne (2012a) argue that crime linkage research studies have used samples which have not been a true representation of what is found in naturalistic settings such as investigative and police settings. For example, the majority of crime linkage research has utilised small samples of solved crime series, whereas in practice, crime linkage is applied to unsolved crimes in criminal investigations (Woodhams & Labuschagne, 2012a). Therefore, a major criticism and limitation of crime linkage research are the samples which have been studied, as they are not representative of what police investigators face in practice (Bennell *et al*., 2014; Pakkanen *et al*., 2021; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a).

For example, it has been suggested that there may have been sample bias in previous crime linkage studies as studies have often only included solved and serial crimes (Cooper & Meterko, 2019; Davies *et al*., 2019). This is viewed as a limitation as offenders who have been convicted of a serial offence which might have been solved in part because of the uniqueness and distinctiveness of the crime scenes, and those which have not been solved or convicted might be in part due to their lack of uniqueness or distinctiveness (Woodhams & Labuschagne 2012a). In other words, suggesting that unsolved cases were less similar and/or distinct, and therefore, more difficult to link and solve, as opposed to solved cases which possibly display more consistent and unique behaviours, making them easier to link, and therefore, solve (Bennell & Jones, 2005). As a result, it has been suggested that studies may overestimate that crimes are linked based on the literature and research on solved serial offences (Woodhams & Labuschagne, 2012a). Therefore, there has been a concern regarding the findings of crime linkage, as to whether they are generalisable, ecologically valid, and applicable to unsolved series still under investigation (Davies *et al*., 2012; Sorochinski & Salfati, 2010; Tonkin *et al*., 2017; Woodhams & Labuschagne, 2012a).

As mentioned, the first study to address one of the major criticisms of crime linkage research regarding the ecological validity of samples by including unsolved linked crimes (confirmed through DNA) was Woodhams and Labuschagne (2012a) who examined serial rape in South Africa. In crime linkage, it is important to have data which has an element of ground truth when testing and examining the principles of crime linkage (Burrell *et al*., 2024; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). For example, in solved cases researchers know that an offender is linked based on being convicted for the crimes. However, in unsolved cases, the offender has not yet been identified or apprehended. Therefore, Woodhams and Labuschagne (2012a) addressed this concern for unsolved crimes by including cases where an offender was not yet caught or apprehended however, cases were linked forensically through DNA. This is because, if cases are connected based on being linked thorough forensic evidence such as DNA, researchers can be certain that the same offender is responsible for the crimes (Woodhams & Labuschagne, 2012a).

As a result, linking unsolved crimes through DNA establishes the ground truth needed to determine the accuracy of linked predictions which is necessary for crime linkage (Burrell *et al*., 2024). This is because researchers can be confident that those crime were in fact committed by the same person (Burrell *et al*., 2024; Woodhams & Labuschagne, 2012a). As presented earlier, Woodhams and Labuschagne (2012a) were able to successfully test the underlying principles of crime linkage research as linked crime pairs displayed greater similarity than unlinked crime pairs, and the model achieved excellent discrimination accuracy (AUC = 0.88). In addition, Woodhams *et al*. (2019) conducted a much larger, international study using unsolved sexual offences (Woodhams *et al*., 2019). The finding of this study, which is considered one of the largest ecologically valid samples, found further support for the hypothesis that linked crimes are more similar than unlinked crime pairs using Jaccard coefficient (Woodhams *et al*., 2019). In addition, the model was able to successfully distinguish between linked and unlinked crime pairs (Woodhams *et al*., 2019). Unsolved cases were once again measured by the AUC and the model's ability to distinguish offender's behaviour was considered acceptable (AUC = .79, 95% CI = .77 - .81). This supports the consistency and distinctiveness hypothesis underpinning crime linkage (Bennell & Canter, 2002). To date however, no study has conducted crime linkage using unsolved murder series.

Regarding the criticism of only serial crimes being examined, Pakkanen *et al*. (2021) addressed this concern by including once-off murders into their sample of serial murderers and found that linkage accuracy was not impacted. Against their expectations, they found that linked crime pairs could be effectively discriminated from unlinked crime pairs, and that overall linkage accuracy increased to 'outstanding' levels of discrimination accuracy (Pakkanen *et al*., 2021). Pakkanen *et al*. (2021) notably highlight that once-off murders are more likely to be solved and at a quicker rate, as a result of being committed by people who are known to the victim and who may have a close relationship with them. Whereas in serial murder cases, victims are often strangers to the offender and can often be more challenging to solve (Chai *et al*., 2022). Therefore, they suggest it is uncommon that investigators will request for assistance in linking crimes, or that the courts will seek expert testimony regarding the opinion on linking these cases. As a result, Pakkanen *et al*. (2021) state that it would be futile to base crime linkage models on once-off offences. However, the counterargument is that it is unknown whether a case is in fact a once-off crime (Woodhams *et al*., 2019). As a result, it is important that studies include these samples, to test and determine whether once-off offences impact on the accuracy of linking serial crimes.

A further challenge in crime linkage research is referred to as the *class imbalance* problem, which results in low base rates of crime linkage research (Woodhams *et al*., 2019). Low base rates are common and a natural limitation at present in crime linkage research, as the number of linked crime pairs are understandably lower than unlinked crime pairs in crime databases which creates this issue of the class imbalance problem (Ewanation *et al*., 2023; Woodhams *et al*., 2019). This is because the population of serial offenders in limited (Slater *et al*., 2015). As a result, it has been suggested that cost-benefit analysis should be conducted (Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). However, a cost-benefit analysis involved in crime linkage would be incredibly challenging and difficult to measure, as it is difficult to quantify the value of human life (Ewanation *et al*., 2023). For example, the cost of not correctly linking a crime could result in further victims, while incorrectly attributing crimes to an individual could result in waste of state resources, wrongful conviction, and possibly a harsher sentence for an offender as the sentence is based on the perceived risk and criminal propensity of being labelled as a serial murder offender (Davies *et al*., 2021; Labuschagne, 2015a; Labuschagne, 2006, 2012; Sorochinski, 2024; Woodhams & Toye, 2007).

As mentioned previously, for evidence to be submitted to a court in some countries, there are certain standards which must be met which are referred as the *Daubert (1993) Standards* (Pakkanen *et al*., 2015a; Tonkin & Weeks, 2021). Meyer (2007) reviewed the techniques used of expert evidence regarding behaviour evidence analysis in court and found that as a result of not being based on empirically driven data and research, did not meet the legal standards for being considered as scientific based methodology, and cannot be used as evidence in court. Therefore, one of the ways in which crime linkage research is limiting the practical application of their findings is by not reporting error rates, which is important and necessary when providing similar fact evidence to courts (Ewanation *et al*., 2023; Pakkanen *et al*., 2015a). Ewanation *et al*. (2023) also suggest that other performance metrics be provided, which previous studies have not supplied as only hit rates have been reported on.

With regard to decision thresholds, while crime linkage researchers acknowledge that different thresholds should be used at different stages of the investigation and legal phases, they have only reported on one decision threshold (Ewanation *et al*., 2023). For example, studies have set decision thresholds using Youden's index as the cut-off point (Davidson & Petherick, 2021; Pakkanen *et al*., 2021; Slater *et al*., 2015; Winter *et al*., 2013), setting the false alarm rate to 15% (Woodhams *et al*., 2019), and 5% (Tonkin *et al*., 2017). The need for a very strict threshold during the trial phase is to reduce the possibility of wrongfully convicting an offender based on incorrectly linking them to another crime which they did not commit (Ewanation *et al*., 2023; Tonkin *et al*., 2017; Woodhams *et al*., 2019). Wrongfully linking and convicting an offender not only negatively impact the offender as well as their family, but allows for the actual perpetrator to go undetected, which could result in further victimisation (Brooks & Greenberg, 2021; Ewanation *et al*., 2023; Sorochinski, 2024).

Therefore, Ewanation *et al*. (2023) suggest that various decision thresholds are applicable at different stages of the investigation such as during the investigative phase and the trial phase. For example, during the trial phase, a very stringent and strict threshold is appropriate and needed in order to reduce the number of false positives (Woodhams *et al*., 2019). However, this will naturally impact on the number of correctly linked crime pairs (hits) which could result in more misses (incorrectly rejecting crime pairs which are actually linked). Therefore, thresholds can impact and/or enhance court and legal proceedings (Woodhams *et al*., 2019). As a result, Ewanation *et al*. (2023) suggest that researchers use mid-range, lenient, and strict

thresholds at various stages of the investigation and trial phase, which has not been done before.

2.5 RESEARCH GAP AND NEED FOR THE CURRENT STUDY

For crime linkage to be empirically supported, the two underlying principles of consistency and distinctiveness need to both be valid (Woodhams & Davies, 2021). Few studies have examined and tested the behaviour consistency and distinctiveness of serial murder offenders, which form the underlying theory of crime linkage (Pakkanen *et al*., 2021; Salfati, 2019). Furthermore, there is a need to determine whether behaviour consistency and distinctiveness exists among a sample of serial murder offenders in South Africa, due to some of the cultural differences observed among serial murders in order to generalise the principles of crime linkage across countries (Pakkanen *et al*., 2021; Sorochinski *et al*., 2015). In addition, the functional domain approach has yet to be explored using a sample of serial murder offenders. Therefore, it is important for investigative purposes to determine whether all crime scene (MO) behaviours are more effective at linking purposes, or whether different functional domains are more helpful for determining whether crimes are connected (Bennell *et al*., 2021; Tonkin, 2015).

As noted above, the main limitations and criticisms of previous crime linkage studies have been because of only using solved series, as it has been suggested that solved series were more distinguishable, and thus easier to link and therefore solve (Davies & Woodhams, 2019; Tonkin *et al*., 2012b; Woodhams & Labuschagne, 2012a). Therefore, there is a need to test the underlying principles of crime linkage using ecologically valid samples to provide empirical support for them (Woodhams *et al*., 2019). Crime linkage studies examining serial sexual offenders have attempted to address this limitation by using unsolved cases which were linked forensically such as through DNA (Woodhams & Labuschagne, 2012a; Woodhams *et al*., 2019). However, to date, there is no crime linkage study which utilises unsolved cases when testing the principles of crime linkage using a sample of serial murder offenders.

Finally, while previous crime linkage studies have acknowledged the need for error rates to be reported for the admissibility of crime linkage as similar fact evidence in court, studies have either not provided error rates or have only reported on the decision outcomes by

applying one decision threshold to the sample being studied (Ewanation *et al*., 2023; Woodhams *et al*., 2019). Consequently, for practical implications, and in order to improve the application of crime linkage research, there is a need for various decision thresholds to be reported on which can be applied during different phases of the investigation and trial phases (Ewanation *et al*., 2023). This is necessary and important to demonstrate the impact on linkage decisions, performance metrics, and resulting error rates of such thresholds, which is needed in legal contexts (Ewanation *et al*., 2023; Turvey, 2012b; Woodhams *et al*, 2019).

2.6 CHAPTER CONCLUSION

This chapter provided an overview of serial murder in terms of the various definitions used as well as the definition chosen for this study. Classification and typologies of serial murderers were presented before highlighting the offence characteristics of serial murder offenders within the South African context regarding offender and victim characteristics. After briefly introducing criminal profiling, the importance of crime linkage was presented by discussing the two theoretical underlying assumptions of crime linkage as well as the benefits of crime linkage during the investigative and trial stages. Various empirical studies were illustrated to demonstrate the different approaches and methodologies used to test the assumptions of crime linkage among different crime types. Thereafter, a critical review of existing crime linkage research was presented, indicating criticism of previous crime linkage research studies regarding the ecological validity of the samples used, as well as how the findings have been presented which have had limited practical applications. This highlighted the current gaps of knowledge in crime linkage, the opportunity for research, and the need for the current study. The following chapter highlights the research methodology used in this research study to address the above-mentioned limitations of existing crime linkage research.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 CHAPTER PREVIEW

This chapter explains the research methodology and procedures which were utilised in the study. It begins by presenting an overview of the research design and the type of methodology implemented. A description of the sample is provided, followed by an explanation of the research procedure, including the data collection and statistical analysis methods used. Issues regarding quality and reliability of data are presented within each section, and the ways in which the researcher addressed and mitigated these concerns, such as how interrater reliability and ecological validity were established. Lastly, the researcher describes how ethical and legal issues were addressed.

3.2 RESEARCH DESIGN AND PROCEDURE

3.2.1 Ethics Approval

Before the study could commence, ethical approval was requested and granted by the University of the Witwatersrand (WITS) Human Research Ethics Committee (HREC) (Non-Medical) on the 2nd of November 2020 (**Appendix B**: Protocol Number: H20/09/29). In addition, permission to conduct research in the SAPS was accepted and approved on the 21st of October 2020 (**Appendix C**: Ref 3/34/2 dated 2020/09/30).

3.2.2 Research Approach

This research study utilised a retrospective transverse case file review and employed a quantitative research design, consistent with the positivist approach (Park *et al*., 2020). An overview of the research procedure followed is provided in **Figure 3.1** below. Tonkin (2015) refers to this approach as the 'Bennell approach', which is in reference to Professor Craig Bennell, who has been one of the pioneers in developing the processes and methodologies used in the field of crime linkage research.

3.3 SAMPLING

The study used purposive sampling as serial offenders, such as serial murderers, are not evenly distributed in society (Davidson & Petherick, 2021; Pakkanen *et al*., 2021). Purposive sampling identifies and categorises individuals with specific characteristics, knowledge, or

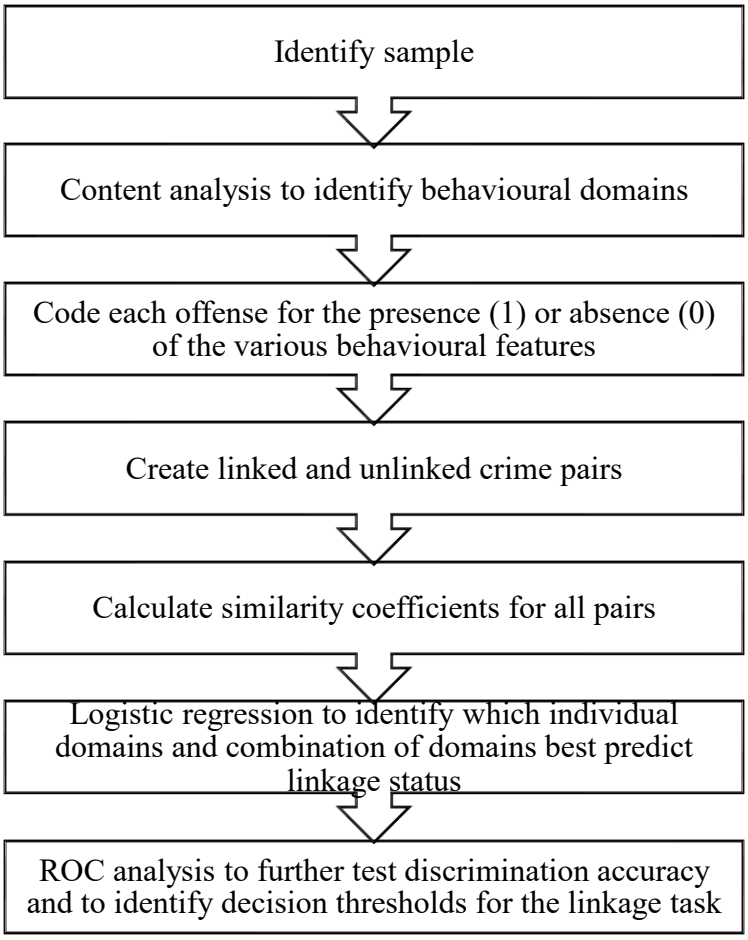


Figure 3.1 Adaption of "the Bennell approach to behavioural consistency, distinctiveness, and discrimination accuracy" (Tonkin, 2015, p.114).

experience, which are relevant to the study (Campbell *et al*., 2020). The main inclusion criteria for the sample for the study was to collect 10 solved and 10 unsolved (but forensically linked) murder series, selected at random by the SAPS IPS members, to produce a total sample size of 20 murder series. This sample size was selected as it is similar to previous crime linkage research studies conducted on serial murder (Pakkanen *et al*., 2021). Furthermore, it was important to obtain similar sample sizes of solved and unsolved murder series in order for them to be comparable. However, during the data collection phase, one of the murder series was initially incorrectly identified as unsolved. It was later determined to have been solved and, therefore, was included to the sample of solved series instead, which resulted in an additional solved murder series. Murder series were defined as being serial murder cases using the operational definition of serial murder used by SAPS IPS, which is at least two murders, committed on two separate occasions, by the same offender(s) (Labuschagne, 2015b; Labuschagne, 2021). The definition utilised in the study corresponds with the FBI's BAU definition of serial murder which is, "The unlawful killing of two or

more victims by the same offender(s) in separate events" (Morton & Hilts, 2008, p. 9). Any other crime series which did not fit within the above-mentioned definition were excluded from the study.

Solved murder series included cases which were closed, fully resolved cases, and where there had been a conviction. Unsolved murder series included serial murder cases identified by the IPS which had been connected forensically, such as through DNA or fingerprints, to an unknown offender, as done in previous crime linkage studies (Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). To test the accuracy of linked predictions, it was important to confirm series membership using forensically linked cases in order to establish a ground truth (Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). This is important for the researcher to be confident that the same person is responsible for committing the crimes, which is crucial in crime linkage research (Burrell *et al*., 2024; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). Individual cases from the unsolved murder series' which were linked behaviourally by the IPS, but which were not linked by forensic evidence, were excluded from the study.

To address issues regarding ecological validity, unsolved murder series were included to address one of the limitations of previous crime linkage research studies of sample bias (Bennell & Jones, 2005). These studies received criticism for only including solved murder series, which is not representative of what occurs in practice, as law enforcement works with unsolved crimes (Pakkanen *et al*., 2021; Tonkin *et al*., 2012b; Woodhams & Labuschagne, 2012a). In addition, it has been suggested that the solved crime series were solved as they were similar in terms of MO and, as a result, easier to link to one offender and therefore, solve the case (Woodhams & Labuschagne, 2012a).

As a result, members of the IPS identified a total of 21 murder series in South Africa which comprised of 126 victims (mean number of crimes per series = 6; range = 2-26). Within the sample, there were 79 (62,7%) solved cases from 11 different murder series, and a total of 47 (37,3%) unsolved (but forensically linked) cases, which resulted from 10 different unsolved murder series. **Table 3.1** provides a summary of the cases used for the study. To protect anonymity and confidentiality of victims, only aggregated data is presented so that series and/or cases are not identifiable.

Table 3.1

Summary of Cases Used in the Study.

Case ID	Series Status	Year of First Known Victim	Year of last Known Victim	Total Number of Victims	Number of Victims Murdered	
					n	*%*
1	Solved	2008	2013	2	2	100%
2	Solved	2007	2012	26	23	88%
3	Solved	2007	2007	4	3	75%
4	Solved	2004	2008	18	9	50%
5	Solved	2014	2017	5	3	60%
6	Solved	2013	2014	4	4	100%
7	Solved	2007	2007	5	5	100%
8	Solved	2010	2011	4	4	100%
9	Solved	2009	2009	2	2	100%
10	Solved	2005	2009	4	2	50%
11	Solved	2015	2018	5	5	100%
12	Unsolved	2003	2007	2	2	100%
13	Unsolved	2004	2013	7	6	86%
14	Unsolved	2020	2020	5	5	100%
15	Unsolved	2018	2018	3	3	100%
16	Unsolved	1999	1999	3	3	100%
17	Unsolved	2020	2021	4	4	100%
18	Unsolved	2016	2020	6	6	100%
19	Unsolved	2001	2003	3	3	100%
20	Unsolved	2016	2018	6	5	83%
21	Unsolved	2009	2010	8	4	50%

All known victims were included within a series, irrespective of how many victims there were beyond two murders. Each victim of murder, as well as surviving victims, such as victims of rape and/or attempted murder within a series committed by the same offender were included, in other words, the entirety of the series was included (Horning *et al*., 2015; Salfati, 2019). Regarding the unsolved series, surviving victims were linked through DNA to deceased victims (or vice versa), and in the solved series, all cases which the offender had been convicted for were included. This was necessary as it is important to examine an

offender's full series in order to determine the change in behaviour (Salfati, 2019). Surviving victims in a series were also included, as this is what is found in naturalistic settings (Horning *et al*., 2015; Sorochinski & Salfati, 2010). Therefore, any surviving victims were included, which is what has been done and recommended in previous serial murder research (Horning *et al*., 2015; Salfati *et al*., 2015a; Salfati, 2019). In the current study, eight of the 21 series (38.01%) included surviving victims, whereas all known victims were murdered in 13 series (61.90%). The researcher ascertained that it was important to determine whether there was consistency to offenders' behaviour with regard to murdering all victims within a series, or whether some offenders were consistently inconsistent within a series, as suggested in previous research (Salfati, 2019; Sorochinski & Salfati, 2010, 2019). This was done to be as realistic as possible, and to replicate what practitioners experience in practice, such as during police investigations, to enhance ecological validity of the study (Davidson & Petherick, 2021; Woodhams & Labuschagne, 2012a). Although there may be concerns that prolific offenders may obscure the data, previous research has indicated that series with high number of victims did not impact discrimination accuracy (Woodhams & Labuschagne, 2012a).

A further criticism of previous crime linkage research with regard to sampling, is that there has been a predominant focus on only including serial offences (Bennell *et al*., 2015; Pakkanen *et al*., 2021). However, Pakkanen *et al*. (2021) argue that serial murder is a heterogenous group of offenders, and the purpose of linking crimes is based on an offender committing two or more offences so that a linkage can be determined. As a result, Pakkanen *et al*. (2021) argue that it would be futile to make a model of crime linkage based on once-off murderers. However, it could be argued that investigators are not aware whether a case is a single case of murder, or whether it is connected to a murder series (Woodhams *et al*., 2019). Nevertheless, this point of exploration was outside the scope of the present study, as the purpose of the research was to examine whether behaviour consistency and distinctiveness exists among serial murder offenders in South Africa.

3.4 DATA COLLECTION

Data were obtained through primary sources such as reviewing the SAPS IPS case files. Case files were accessed on site at the head office of the IPS in Pretoria, South Africa. These files were compiled by the IPS members when assisting with serial murder cases in the course of their investigative duties, which contained copies of the investigation files (referred

to as a ‘docket’ in SAPS terminology) for each criminal incident (e.g. a murder, a rape, an attempted murder), and sometimes court documents. Data collection commenced in November 2020 after obtaining ethical approval and permission from the SAPS and was completed in July 2023. To achieve the research aims of the study, the researcher conducted an extensive content analysis of police case files to describe and compare the crime scene behaviour in each murder series. The purpose of this was to increase the ecological validity of the study by ensuring that the information used in this research matched the information available to investigators when conducting investigations for active cases (Woodhams & Labuschagne, 2012a).

The SAPS use hard-copy files for the compilation of the investigation and do not utilise an electronic system for record keeping. Thus, the three main sources of information were: The IPS files, the investigation case files/dockets, and court records from the trial (where available in the case of convicted cases). In addition to the IPS member’s own investigation diary together with the information they may have collected in the course of their duties, the IPS case files typically contained the following: copies of information from the SAPS investigation files which included crime scene photographs; witness statements; forensic reports (e.g. DNA, ballistics, toxicology); forensic pathology autopsy reports; the investigation diary of the investigating officer; court records; and crime matrices, where available. It was important to consult and consider multiple sources of information in order to gain as much detailed information as possible for each of the crime scenes being examined, to ensure that the data obtained for the study was reliable (Guba & Lincoln, 2005). As mentioned, using original police case files increases the practical relevance and ecological validity of the study, which is important for the reliability and validity of crime linkage research (Bennell & Jones, 2005; Davies & Woodhams, 2019; Salfati *et al*., 2015b; Woodhams & Labuschagne, 2012a).

The researcher then developed a *behavioural checklist* (see **Appendix D** for the full behavioural checklist per functional behavioural domain) to record all crime scene behaviours which was important in order to empirically test the behaviour consistency and distinctiveness of offender’s using all crime scene behaviours. However, instead of only determining whether all crime scene MO behaviours were effective at linking crimes overall, crime scene behaviours were further categorised into functional behavioural domains in this study. As a result, the behavioural checklist made it further manageable and accessible to

categorise behavioural variables into functional behavioural domains. This chosen level of analysis was selected since MO may change and evolve over time, as a result of situational and contextual factors, such as learning and maturation of the offender (Bennell *et al*., 2015). Another level of analysis, namely examination of psychological themes (Salfati, 2015) could have been chosen. However, the researcher chose the functional domain analysis as it is considered to be advantageous due to being a more efficient and pragmatic way of determining which behaviours are more helpful, or less helpful, for linkage purposes (Bennell *et al*., 2021; Bennell *et al*., 2015; Bennell & Canter, 2002; Tonkin *et al*., 2012a; Tonkin & Woodhams, 2017).

A limitation across crime linkage research is that there is no standardised checklist of crime scene behaviours, or functional behavioural domains. As a result, categorising behaviours into functional behavioural domains from the behavioural checklist was done by adapting the Tonkin *et al*. (2012a) study, who divided their behavioural variables into their assumed function. Tonkin *et al*. (2012a) proposed and considered the following functional domains and subsequent crime scene behavioural variables in their study: *control behaviours* (what method was used in order to control the victim, for example what types of weapons were used); *style behaviour* (what behaviour occurred which was not necessary for the crime, the signature); *sexual behaviour* (was there penetration, how were they penetrated, etc.); and *target selection variable* (gender, race, age of the victim, the victimology, geographical considerations). The functional domain approach is a pragmatic, atheoretical approach to examine the behaviour of offender's (Bennell *et al*., 2015; Tonkin, 2015).

The researcher further developed these domains for the current study with the assistance of current and ex-operational members of the SAPS' IPS, based on the type of 'matrix' used when analysing cases in active investigations (Labuschagne, 2021a). A total of 129 variables were used in the statistical analysis of the study. The crime scene behaviours were identified and categorised into four functional behavioural domains which consisted of 30 *target selection* variables (for example, age of victim (categorised into toddlerhood [0-3years]; childhood [4-8years]; prepubescent [9 – 12 years]; adolescence [13-17 years], adulthood [18 – 64], and elderly [65 years and above]), race, gender [biological sex], occupation status); 29 *sexual behaviours* (for example for the purposes of committing a sexual act such as, penetration, evidence of ejaculation, state of victim undress); 34 *violence and control* behaviours (for example, what was used to control the victim, any restraints used, weapon/s

used, injuries, cause of death); and 36 *crime scene characteristic* variables (for example where the body was discovered, the type of location, forced entry, items taken, position of body – essentially, "what would investigators observe when they get to the crime scene?"). Behaviours that did not feature in any of the crime scenes (for example, Asian victim, cause of death resulting from a gunshot, cause of death resulting from poisoning, seminal fluid found in the victim's mouth), were removed from the analysis. In other words, only observed variables were included, thereby removing variable redundancies (Bennell *et al*., 2015, 2021).

For this study, the researcher considered the importance and necessity of consulting SAPS following the process of content analysis, in order to verify whether appropriate and applicable variables were used and operationalised in the appropriate functional behavioural domains, based on their assumed function. It has been reported that practitioners are often reluctant to hand over responsibility or discuss methods used to link crimes, as they report that they need to be responsible for any linkage decisions made (Bennell *et al*., 2015). However, most crime linkage methods require some degree of input from practitioners, for example, in the current study, deciding which behaviour/s to include in the functional behavioural domain analysis (Bennell & Woodhams, 2015). The researcher believed that the crime practitioners' experience and input was invaluable and necessary to provide a meaningful and effective study, and SAPS IPS were forthcoming and assisted with all information which is to be commended.

3.4.1 Data Reliability

Data were coded using a binary coding system, with a behaviour being present marked as one (1), and zero (0) for not present or absent/missing. This was to limit any complications of coding the data as the data fields recorded the presence or absence of a behaviour, and did not require interpretive or subjective judgment of the researcher to record the data. This is in line with one of the four aspects of *pragmatism* which considers how user friendly a coding system is, taking coding fatigue into account, and reducing any complex manner of coding of behaviour variables, as this will impact on the model's reliability (Bennell *et al*., 2015a).

Although a strength of the current study is that it used original police case files which increased ecological validity by representing naturalistic settings and thereby enhancing practical relevance (Santtila *et al*., 2008), information used and gathered from police case files are not usually or commonly gathered for research purposes (Woodhams & Labuschagne, 2012a). As a result, there may be some information which was not deemed necessary or important during the investigation however, it could have been relevant to the study (Woodhams *et al*., 2019). Therefore, researchers are limited by the data which they are provided (Salfati, 2021). International research studies suggest that police case files are reportedly found to have inherent methodological biases (Chopin & Aebi, 2019; Reale *et al*., 2021; Salfati, 2021). This is due to being impacted by the investigators experience, training, subjective understanding, and opinions (Salfati, 2021). This can be viewed as a possible limitation as the quality of the data can, for example, be impacted by poor police investigative work, poor quality crime scene photos, and poor documentation of crime scene characteristics (Bennell *et al*., 2021; Woodhams & Labuschagne, 2012a). One of the most important factors when it comes to crime linkage, is the reliability of the data collected and coded (Bennell *et al*., 2021). No statistical method of analysis is useful or beneficial if the data collected is unreliable (Bennell *et al*., 2015a). This was important to consider as the researcher needed to ensure that the data was as reliable as possible (Bennell *et al*., 2015a; Ewanation *et al*., 2023).

To address and mitigate this limitation, the researcher attempted to gain as much information as possible by collecting data from multiple sources of information, and then cross referencing these sources of information with one another (Ewanation *et al*., 2023; Winter *et al*., 2013). For example, the sources referred to were: the post-mortem autopsy results; the investigation diary of the detective; the crime scene photographs; witness statements where possible; consultation with the IPS member allocated to the case if available; as well as court documentation. Furthermore, as discussed below within the statistical analysis section, Jaccard's similarity is sensitive to variation in the data, and is not impacted by missing information (Bennell, 2005; Bennell *et al*., 2014; Bennell & Canter, 2002).

3.4.1.1 Interrater Reliability

To ensure objectivity and reliability of the coding, an independent analyst/coder who is employed by SAPS and who is familiar with serial murder, was consulted to identify and

address any potential blind spots such as coding bias, coding errors, and to obtain inter-rater reliability of the coding (Cooper & Meterko, 2019; Davies & Woodhams, 2019; Woodhams & Labuschagne, 2012a). It is important to note that the purpose of consulting another coder was to determine if there were alternative ways of interpreting and coding the data, whether alternative conclusions could be drawn, or whether the data coded for the study can be seen as reliable (Woodhams & Labuschagne, 2012a). For example, the researcher had initially included 'days of the week' in which the victim was murdered however, it was later excluded and removed from the analysis. It was excluded from the statistical analysis as there was discrepancy with regard to when the victim was murdered, it was often either based on when the victim was last seen alive, and/or when the body was discovered. The researcher ascertained that this could result in unreliable information gathered and create confusion in future analysis.

As a result, interrater reliability was used to safeguard the validity and reliability of the data coded. Put differently, would other researchers such as future researchers code the data the same way if faced with the same data, and would they be able to replicate the analysis of the study (Bennell *et al*., 2010; Pakkanen *et al*., 2012). The percentage agreement and Cohen's kappa (κ) statistic were calculated to assess if there was agreement between the researcher and the independent coder, who coded 10% of the sample (Woodhams & Labuschagne, 2012a). Cohen's κ assesses agreement between coders and takes chance or guessing into consideration (Li *et al*., 2023). Notably, McHugh (2012) argued that since Cohen's κ is an *estimated* level of interrater reliability (as it includes levels of chance and guessing) and is not a *direct* measurement between the two coders therefore, it is recommended that researchers provide both the percentage agreement and Cohen's κ (McHugh, 2012).

The percentage agreement between the two coders in the above dual-coded sample had 93% agreement. With regard to Cohen's κ there was a 70% agreement overall between the coders; $\kappa = .70$ (95% Cl, .745 to .651), $p < .001$ which is considered 'substantial' (Cohen, 1960) and 'moderate' agreement (McHugh, 2012). This value is consistent with agreement found between coders in previous crime linkage research (Pakkanen *et al*., 2021; Woodhams & Labuschagne, 2012a). Once the sample was identified, coded and interrater reliability was established, statistical analysis was conducted on the datasets which is expounded upon below.

3.5 STATISTICAL ANALYSIS

Descriptive statistics of behavioural variables were first generated to compare the sample between solved and unsolved murder series. Thereafter, this study used the *gold standard* method (Burrell *et al*., 2024; Woodhams *et al*., 2019) to determine whether behaviour consistency and distinctiveness exists among a sample of solved and unsolved murder series in South Africa. As mentioned previously, the gold standard refers to a combination of the following statistical analysis: *Jaccard's coefficient* as the method to determine similarity of crime pairs, *logistic regression* to predict the linked status of crime pairs, and the *ROC curve* and *AUC value* to assess the accuracy of the linked status predictions resulting from the model (Burrell, 2022; Burrell *et al*., 2024; Davidson & Petherick, 2021; Tonkin, 2015; Woodhams *et al*., 2019).

Overall, there were five main sets of data. **Table 3.2** provides a summary of the datasets which were subjected to statistical analysis. The first dataset consisted of *all crime scene MO behaviours.* Datasets two to five examined the following functional behavioural domains: the second dataset consisted of all *target selection* variables; the third dataset consisted of all *sexual* variables; the fourth dataset consisted of all *violence and control* variables; and lastly, the fifth dataset consisted of *the crime scene characteristics* variables. Within each of the five datasets, there were three subsets of data which included: *all variables* (solved and unsolved cases); *all solved* (excluding unsolved cases); and *all unsolved* (excluding solved cases). Therefore, there was a total of 15 sets of data which were subjected to inferential statistical analysis, which included four sets of analysis (referred to as steps one to four). The statistical analysis selected were to test the underlying principles of crime linkage research namely behavioural consistency and distinctiveness of offenders' behaviours (Davidson & Petherick, 2021; Tonkin, 2015). Statistical analyses were conducted by the researcher and were performed using IBM SPSS (Version 29.0.2.0), after consultation with an international crime linkage researcher who guided test selection.

All levels of statistical analysis were conducted on all datasets, which included: all data (solved and unsolved), all solved data (unsolved excluded), and all unsolved data (solved excluded). The decision to run separate analysis was justified, as comparing the AUC values between solved and unsolved datasets is highly beneficial and important to the field of crime linkage, as the results could have implications for the interpretation of prior research

Table 3.2

Summary of Datasets and Sub-datasets Subjected to Statistical Analysis.

Dataset #	Dataset/Domain	Data Subset	Data Analysis Steps
1	All MO Behavioural Variables	i) All behavioural variables (solved and unsolved); ii) All solved behaviour variables (unsolved excluded); iii) All unsolved behavioural variables (solved excluded)	All Analysis (steps 1 – 5)
2	Target Selection Domain	i) All target selection variables (solved and unsolved); ii) All solved target selection variables (unsolved excluded); iii) All unsolved target selection variables (solved excluded)	Steps 1 - 4
3	Sexual Domain	i) All sexual theme variables (solved and unsolved); ii) All solved sexual theme variables (unsolved excluded); ii) All unsolved sexual theme variables (solved excluded)	Steps 1 - 4
4	Violence & Control Domain	i) All violence & control variables (solved and unsolved); ii) All solved violence & control variables (unsolved excluded); iii) All unsolved violence & control variables (solved excluded)	Steps 1 - 4
5	Crime Scene Characteristics Domain	i) All crime scene characteristic variables (solved and unsolved); ii) All solved crime scene characteristics (unsolved excluded); iii) All unsolved crime scene characteristics (solved excluded)	Steps 1 - 4

(Davidson & Petherick, 2021; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). For example, if the results of the statistical analysis for the unsolved dataset was significantly different and lower in comparison to the solved dataset, this could challenge the assumption of consistency and distinctiveness of offenders as previous research supporting the hypothesis only included solved cases (Melnyk *et al*., 2011; Pakkanen *et al*., 2021). Based on the results, dataset one had an additional (fifth) set of analysis, referred to as step five, which will be discussed further below.

3.5.1 Step One: Create Crime Pairs and Determine Similarity Scores

Once the sample was identified, behavioural variables coded, and inter-rater reliability was established, the first step was to create crime pairs and calculate Jaccard's similarity coefficient scores for each crime pair. Determining similarity scores of crime pairs was important to test one of the underlying assumptions of crime linkage namely, behavioural consistency (Bennell & Canter, 2002). Jaccard's coefficient compares binary sets of data to determine the behavioural similarity score of each crime pair (Bennell & Canter, 2002). For example, creating a similarity score for crime-series-one; victim-one, with crime-series-two; victim-one, and so forth, until all crime pairs had been compared within and across all series. A statistical program called B-LINK, developed by Professor Craig Bennell in 1999 (Bennell & Canter, 2002), was used for this study as it has been specifically developed for the pairwise crime linkage task (Bennell *et al*., 2009; Bennell & Canter, 2002; Woodhams & Labuschagne, 2012a).

B-LINK calculates Jaccard's similarity coefficient scores of each crime pair using the following formula: "J=a/(a+b+c)" (Melnyk *et al*., 2011, p. 360). Within the formula, *a* is equal to the number of behaviours exhibited in both crime scenes, and *b* and *c* are equal to the number of behaviours equal to crime scene one and crime scene two respectively (Bennell & Canter, 2002; Melnyk *et al*., 2011). Jaccard coefficient scores closer to one (1) indicate perfect similarity between crime pairs, while similarity scores of crime pairs closer to zero (0) indicate complete inconsistency (Bennell *et al*., 2009; Davidson & Petherick, 2021; Slater *et al*., 2015). The purpose is to establish whether a crime pair can be linked based on their similarity index score (Bennell & Canter, 2002).

Jaccard's coefficient is reported to be the most appropriate coefficient to quantify behavioural similarity in crime linkage research due to its simplicity, validity, and sensitivity to variation in the data (Bennell & Canter, 2002; Ellingwood *et al*., 2013; Melnyk *et al*., 2011; Woodhams *et al*., 2019). As discussed previously when addressing data reliability, this was important to consider as crime scene data from police case files could have missing information, as the data were captured for investigative purposes and not research purposes, and behaviours may not have been accurately reported (Woodhams *et al*., 2019). Therefore, ignoring joint non-occurrences of behaviour is useful, as the absence of a behaviour at a crime scene is not necessarily indicative that a behaviour did not in fact occur (Melnyk *et al*., 2011). Put differently, it does not increase similarity of a crime pair based on joint non-occurrences (Davidson & Petherick, 2021). As a result, Jaccard's similarity coefficient was selected when quantifying similarity of crime pairs to reduce this concern, as joint non-occurrences of a specific behaviour are not included and, therefore, is sensitive to variation in the data due to the above examples (Bennell & Canter, 2002; Davidson & Petherick, 2021; Melnyk *et al*., 2011).

Binary coding for each behavioural variable was done for all 129 variables. B-LINK then provided a quantitative measure of how similar each crime pair was in terms of behaviour, based on the Jaccard's similarity coefficient similarity score, which is used to establish whether behavioural consistency exists (Davidson & Petherick, 2021; Tonkin *et al*., 2012b; Woodhams & Labuschagne, 2012a). A similarity coefficient was produced for all crime pairs which included linked crime pairs, as well as unlinked crime pairs (Woodhams & Labuschagne, 2012a).

3.5.2 Step Two: Assessing Distribution of Data

Previous crime linkage research studies have determined that crimes committed by the same offender typically have higher *across crime* similarity scores, thereby exhibiting behavioural consistency (Bennell & Canter, 2002; Ewanation *et al*., 2023; Woodhams & Labuschagne, 2012a). In addition, the degree to which the distribution of the across crime similarity scores overlap, suggest which behaviour/s can distinguish between crimes committed by one offender, versus another offender (Bennell *et al*., 2009; Bennell & Canter, 2002; Ewanation *et al*. 2023; Woodhams & Labuschagne, 2012a).

Boxplots were configurated using DATAtab (2024) and provided useful visual representations of the distribution of the data of linked and unlinked crime pairs. Boxplots display the median, quartiles, outliers, and range or dispersion of the values within each domain (Krzywinski & Altman, 2014). Displaying boxplots next to one another provides a visual comparison of distribution across datasets (Simonini *et al*., 2024). Despite the visual presentation of the distribution of the data, the second step was to run the *Kolmogorov-Smirnov* test on the linkage status and Jaccard's coefficient scores to determine whether there was a normal distribution of data, or whether the null hypothesis was rejected (Pallant, 2020).

All sets of data demonstrated that they were significantly different to the null hypothesis of normal distribution, and therefore, non-parametric tests were relevant and conducted next. As a result, *Mann-Whitney U* tests were conducted to determine whether linked crime pair's Jaccard's coefficients were significantly different to unlinked crime pairs, as done in prior crime linkage research (Bennell & Canter, 2002; Davidson & Petherick, 2021; Slater *et al*., 2015; Tonkin *et al*., 2012a; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). The importance of establishing whether linked crime pairs were significantly different and larger than unlinked crime pairs, was important to determine one of the assumptions of crime linkage namely behaviour similarity (consistency) across crimes (Bennell & Canter, 2002). In other words, the following two hypotheses need to be true: linked pairs show a high level of similarity closer to "1" (and therefore, behaviour consistency); and low behavioural similarity scores closer to "0" for unlinked crime pairs (therefore, dissimilar behaviour) (Woodhams *et al*., 2019). The extracted pairs calculated from Jaccard's coefficient, run from B-LINK, were then applied to the logistic regression model to generate the predicted linked status (Woodhams *et al*., 2019).

3.5.3 Step Three: Predicting Linked Status of Crime Pairs Using Binary Logistic Regression Analysis and Cross Validation of Data

The third step was to conduct a *binary logistic regression analysis* as commonly done in previous crime linkage research (Bennell *et al*., 2015; Tonkin *et al*., 2012a; Woodhams *et al*., 2019). Logistic regression analysis predicts the binary status of crime pairs from across-crime similarity scores to determine whether linked crime pairs can be distinguished from unlinked crime pairs (Bennell & Canter, 2002). There are two main approaches to examining functional domains, namely *Logistic Regression Analysis* and *Classification Trees analysis*

(Bennell *et al*., 2015; Tonkin *et al*., 2012c). Logistic regression is commonly understood among researchers, practitioners, and professionals as opposed to other methods which is one of the reasons it is the preferred method used in crime linkage research (Bennell *et al*., 2015). Tonkin *et al* (2012c) further found that logistic regression was more accurate in their study. As a result, the researcher chose to use binary logistic regression analysis, as it is the most common approach used in crime linkage research (Bennell *et al*., 2015a; Ewanation *et al*., 2023; Woodhams *et al*., 2019). Furthermore, logistic regression analysis is considered more useful as it allows the researcher to determine the predictive power of a combination of behavioural variables, as well as specific functional domains (Tonkin *et al*., 2012a).

To cross-validate the logistic regression model and ensure validity of the data, the LOOCV method was utilised, as done in previous crime linkage research studies (Santtila *et al*., 2008; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). LOOCV is a machine learning technique which conducts a thorough evaluation of a model's performance and is the preferred method (as opposed to the split-half validation method) in crime linkage as it is considered to be much more efficient, as all cases within a sample are systematically tested (Bennell *et al*., 2015a). The LOOCV method is beneficial as it splits the data multiple times, particularly when the sample is considered small, to prevent overfitting of the model (Bennell & Woodhams, 2015; Woodhams *et al*., 2019). Splitting the data multiple times prevents the model from becoming too complex and learning training data too well, to the point where the model fails to generate to new, untested and unseen data (Winter *et al*., 2013). The LOOCV method extracts each crime pair from the sample sequentially. The crime pair is then returned to the sample and the next crime pair is extracted, and the process is repeated, resulting in a performance estimate based on the average of all predictions until a predicted probability value has been determined for each crime pair (Tonkin *et al*., 2012a; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). This predicted probability value is then use as the dependent variable, and the linked status as the independent variable to produce ROC curves and AUC values (Bennell *et al*., 2015).

3.5.4 Step Four: Assessing Predictive Accuracy Using ROC and AUC

The fourth step was to determine the discrimination accuracy of the linked predictions. In crime linkage research, discrimination accuracy can be defined as the ability of a statistical model to differentiate between unlinked and linked crime pairs (Bennell & Canter, 2002;

Tonkin, 2015; Burrell *et al*., 2024). Discrimination accuracy is necessary to test the underlying principles of crime linkage, as it suggests that offenders' behaviours are unique, and as a result, can be differentiated from other offenders (Bennell & Canter, 2002). To do this, ROC analysis was done by using the true linked status of crime pairs as the independent variable, and the predicted probability value obtained from the binary logistic regression model and LOOCV analysis as input for the dependent variable, following previous crime linkage research (Tonkin *et al*., 2012b; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). The ROC analysis provides an indication of overall discrimination accuracy through the AUC value (Bennell & Jones, 2005). This study used the following pre-established guidelines for interpreting and classifying AUC values (Hosmer *et al*., 2013): outstanding (AUC ≥ .90); excellent (.80 ≤ AUC ≤ .90); acceptable (.70 ≤ AUC ≤ .80); and ineffective (AUC ≤ 0.70). Based on the results, significance tests were conducted to calculate AUCs between dataset one, all crime scene MO behaviours, using MedCalc statistical software (version 19.2.6).

As highlighted in the previous chapter, ROC analysis is the most common method used to assess the accuracy of the predicted linked status in which the principles of crime linkage can be examined (Burrell *et al*., 2024). ROC is a popular method as it provides a range of possible outcomes, as demonstrated along the ROC curve (Bennell & Jones, 2005; Ewanation *et al*., 2023; Woodhams *et al*., 2019). ROC and AUC are flexible and unaffected by base rates therefore, they can be compared across datasets characterised by different base rates, as the AUC is not derived from the frequency of decision outcomes, but rather on the proportions of various decision outcomes (Ewanation *et al*., 2023). According to Bennell and Canter (2002), there are four possible outcomes of linked predictions: *hits* (true positives: correctly linking linked crime pairs); *correct rejections* (true negatives: correctly classifying unlinked crime pairs as unlinked); *false alarms* (false positives: incorrectly linking unlinked crime pairs); and *misses* (false negatives: incorrectly classifying linked crime pairs as unlinked). Therefore, *hits* (H) are two correctly linked crimes committed by the same offender (Ewanation *et al*.,2023). *Misses* (M) are two crimes left unlinked which were committed by the same offender (Bennell & Canter, 2002). *False Alarms* (FA) are crimes which were not linked but incorrectly linked as such. While *Correct Rejections* (CR) are crimes which were not committed by the same offender and correctly unlinked (Bennell *et al*., 2015). The AUC value provides a *relative* level of linkage predictive accuracy based on the performance of the linkage approach used. Ewanation *et al*. (2023) criticise previous

crime linkage research studies for only presenting AUC values, and not full ROC curves. As a result, the researcher presented all ROC graphs which achieved effective levels of discrimination accuracy.

While Ewanation *et al*. (2023) agree that ROC analysis with corresponding AUC value is the most common and widely used method for determining discrimination accuracy in crime linkage research, they identified four main limitations which they recommend future research should consider and address. Firstly, they state that researchers are not defining and interpreting the AUC correctly, as the AUC does not measure complete accuracy, but rather provides an *overall* and *relative* level of accuracy (Bennell *et al*., 2021; Ewanation *et al*., 2023). For example, an AUC value of .83 does not suggest that the model correctly classified cases 83% of the time, but rather; that out of a randomly selected crime pairs, linked crime pairs will have higher similarity scores 83% of the time than unlinked crime pairs (Ewanation *et al*., 2023). As a result, Ewanation *et al*. (2023) state that researchers need to explicitly state what the AUC means, and how it can be used. Secondly, they suggest that there is too much emphasis placed on accuracy metrics and not enough focus on decision outcomes (Ewanation *et al*., 2023). This means that, instead of only reporting on *hits* (correctly linked crime pairs), researchers should present contingency tables, to provide a complete understanding and picture of the various decision outcomes such as correct rejections, false positives, and misses (Ewanation *et al*., 2023).

Furthermore, to determine whether a crime pair is or is not the work of the same offender, it has been suggested that *Precision Recall Curves* (PRC) supplement full ROC graphs in cases where there are low base rates, in order to mitigate the concern of imbalanced datasets (Ewanation *et al*., 2023). Low base rate in crime linkage means that there is a significant imbalance between the number of binary classifications (linked and unlinked crime pairs) (Saito & Rehmsmeier, 2015). Low base rates are common in the pairwise crime linkage task, as the number of unlinked crime pairs far outweighs the number of linked crime pairs (Bennell & Woodhams, 2015; Ewanation *et al*., 2023; Woodhams *et al*., 2019). Therefore, PRCs summarise the trade-off between the *Positive Predictive Value* (PPV) and the *True Positive Rate* (TPR) of a predictive model. PRC are useful as true negatives (correct rejections) do not hold value, which is relevant to crime linkage, as it won't consider the correctly unlinked crime pairs, due to the low base rates (Ewanation *et al*., 2023). In other words, PRCs plot hit rates on the *x*-axis, and precision/PPV (positive predicted values) on

the *y*-axis, and are able to distinguish the accuracy of the ROC graph in predicting the likelihood of linked crime pairs being correctly identified as being committed by the same offender, versus unlinked crime pairs committed by different offenders (Ewanation *et al*., 2023). Therefore, to mitigate this issue, the researcher provides PRC graphs to supplement the ROC curves, based on the results of the discrimination accuracy of the datasets, for dataset one when examining all crime scene MO behaviours (solved and unsolved; solved only; and unsolved only).

As the ROC analysis retains and plots all possible decision threshold outcomes along the ROC curve, it is useful to determine which threshold may be necessary and appropriate for different contexts of the crime linkage task (Bennell & Canter, 2002; Bennell & Jones, 2005). Therefore, researchers are able to set different decision thresholds along the *x*-axis of the ROC graph. One of the difficulties in crime linkage is finding a balance between pH and pFA in determining what threshold should be used as there are various implications based on the decision threshold used (Ewanation *et al*., 2023). This assists in identifying the probability of generating different decision outcomes used with different thresholds for practitioners to determine when an ideal linked decision can be made (Ewanation *et al*., 2023; Woodhams *et al*., 2019). As a result, the ROC curve allows researchers to identify decision thresholds which provide the most desirable balance between hits and false positives (Ewanation *et al*., 2023). For example, the higher the number of false positives, the more lenient a decision will be based on whether a crime is the work of the same offender by linking crimes on lower across-crime similarity scores (Bennell *et al*., 2021; Woodhams *et al*., 2019). Conversely, the lower the number of false positives, the stricter the decision made on whether a crime has been committed by the same offender by linking crimes based on higher across-crime similarity scores (Ewanation *et al*., 2023).

The goal is to determine how useful a statistical model might be for predicting the linked status of crimes or cases which are yet to be tested, with a known linkage status (Bennell *et al*., 2015a). The rates of reported predictive accuracy of a statistical model assists in determining how valid and generalisable the study's results are and how effective certain behaviours and samples are in being able to assist in the practice of crime linkage (Ewanation *et al*., 2023; Woodhams *et al*., 2019). For example, linking crimes which are not in fact part of a series could result in incorrect convictions or using a task team's resources unnecessarily (Burrell *et al*., 2024; Woodhams *et al*., 2019). Conversely, by not identifying crimes as being

part of a series potentially allows for an offender to go undetected, which could result in further victimisation and cost to human life (Alison *et al*., 2002; Woodhams *et al*., 2019).

Bennell *et al*. (2015) further suggest that only the portions of the ROC that are practically important, and that are relevant, should be reported on and not thresholds which are practically irrelevant. However, a criticism or limitation of existing research, is that limited, and sometimes undesirable decision thresholds are being used and reported on (Ewanation *et al*., 2023). For example, studies have only reported on the sensitivity and specificity using one decision threshold, which is often Youden's index (= pH+pCR-) (Bennell & Jones, 2005; Pakkanen *et al*., 2021; Slater *et al*., 2015; Winter *et al*., 2013). Youden's index has previously been referred to as the 'ideal' cut off point in crime linkage research as it maximises the number of hits (correctly classifying linked crime pairs [sensitivity]), while minimising the number of false positives (incorrectly classifying crime pairs as linked [1-specificity]) (Pakkanen *et al*., 2021). To address this issue, the researcher reported on the frequency of various decision outcomes such as performance metrics and error rates, which resulted from a range of decision thresholds set. Applying a range of thresholds, expounded upon below, has not been done in previous crime linkage research, despite the acknowledgement that different thresholds are necessary during different phases of the investigative and trial phases (Ewanation *et al*., 2023; Woodhams *et al*., 2019).

3.5.5 Step Five: Decision Thresholds and Performance Outcomes

Based on the results, the fifth and final step of the statistical analysis was to apply various decision thresholds to dataset one and to provide corresponding contingency tables. This analysis was only conducted and applicable to dataset one (which consisted of three sub-datasets) after determining that *all crime scene MO behaviours* were more effective at distinguishing between linked and unlinked crime pairs than functional behavioural domains. This was consistent across datasets, as well as across the various decision thresholds applied (as indicated by the ROC curves). Providing decision outcomes for different decision thresholds set was conducted in order to address a limitation of previous research where the focus was on accuracy metrics such as the AUC, instead of focusing on decision outcomes (Ewanation *et al*., 2023; Woodhams *et al*., 2019). As mentioned above, the AUC indicates a relative level of discrimination accuracy across multiple decision thresholds however, every threshold is not necessarily important (Woodhams *et al*., 2019).

To address this, the researcher provided contingency tables with full ROC curves instead of solely providing the AUC value.

Decision making involving *bandwidth* and *fidelity* is important as it directly relates to the decision of setting thresholds (Bennell *et al*., 2015a). The specific thresholds adopted and applied in a study impacts the level of accuracy reported by the researcher (Ewanation *et al*., 2023). Furthermore, the balance and trade-off between accuracy versus precision had to be considered (Bennell *et al*., 2015; Ewanation *et al*., 2023). Bennell *et al*. (2015) argued that there is typically an inverse relationship between accuracy and precision of crime linkage models. By applying a lenient threshold, there will naturally be more correct linkages made however, at the cost of having more false alarms and incorrect linkages. Therefore, the researcher was mindful that a lenient threshold decreases precision (fidelity) but increases accuracy (bandwidth); whereas a strict threshold will increase precision, but decrease accuracy (Bennell *et al*., 2015a). A stringent threshold would be more applicable for the application of the thresholds in practice, despite the reduced hit rate (Woodhams *et al*., 2019).

As a result, the researcher selected four different thresholds based on careful consideration of previous studies and adopted lenient, mid-range, strict, and very strict thresholds, as recommended by Ewanation *et al*. (2023). This resulted in selecting a 'very strict' threshold with a false alarm rate of 5% (Tonkin *et al*., 2017), a 'strict' threshold with a fixed false alarm rate of 15% (Woodhams *et al*., 2019), a 'mid-range' threshold which analysed the closest "top-left" point on the ROC graph (commonly known and referred to as Youden's Index) (Davidson & Petherick, 2021; Pakkanen *et al*., 2021; Woodhams & Labuschagne, 2012a), and a 'lenient' threshold which had a hit rate of 90% (Ewanation *et al*., 2023). The researcher used the "if then" function in SPSS to recode predicted probabilities to determine the number of linked and unlinked crime pairs, based on the new decision threshold applied to produce contingency tables (Woodhams *et al*., 2019).

To supplement the ROC and AUC for dataset one (all crime scene MO behaviours), the researcher compiled contingency tables with outcomes of the confusion matrix, as recommended by Ewanation *et al*. (2023) to provide further details on the accuracy of the predicted outcomes such as providing DE, MR, NVP, PPV, % correct, likelihood + values, and likelihood - values. *Diagnostic Effectiveness* (DE) is the percentage of correctly

predicted linked crimes. *Misclassification Rate* (MR) is the percentage of incorrectly precited linked crimes. DE and MR do not correctly identify whether predicted crimes are indeed the work of the same offender (Ewanation *et al*., 2023). As a result, *Positive Predictive Values* (PPV) and *Negative Predicted Values* (NPV) assist in identifying the likelihood of predicting whether a linked crime was correctly linked to the crime committed by the same offender (PPV), or whether the unlinked predicted crimes are in fact the work of different offenders (NPV) (Ewanation *et al*., 2023). Providing performance metrics was to address the unbalanced dataset between the number of linked and unlinked cases (Woodhams *et al*., 2019). Performance metrics and matrices were calculated in excel from the contingency table with the decision outcomes. The study used the following formulas provided in **Table 3.3** below, which were obtained and summarised from Ewanation at el. (2023) and Shaikh (2011).

Table 3.3

Summary of Formulas Used to Calculate Performance Metrics.

Performance Metric Measure	**Formula**
True Positive Rate (TPR) (Hit Rate/Sensitivity/Recall)	TPR = TP / (TP + FN)
True Negative Rate (TNR) (Specificity/Correct Rejection Rate)	TNR = TN / (FP + TN)
False Positive Rate (FPR) (False Alarm Rate/1-specificity)	FPR = FP / (FP + TN)
False Negative Rate (FNR) (Missed/unlinked precision)	FNR = FN / (FN + TP)
Diagnostic Effectiveness (DE) (Accuracy/% Correct)	DE = (TP + TN) / (TP + TN + FP + FN)
Misclassification Rate (MR) (Error rate)	MR = (FP + FN) / (TP + FP + FN + TN)
Positive Predictive Value (PPV) (Precision)	PPV = TP / (TP + FP)
Negative Predicative Value (NPV) (Unlinked Recall)	NPV = TN / (TN + FN)
False Discovery Rate (FDR) (1-precision)	FDR = FP / (FP + TP)
+ Likelihood Ratio (LR+) (linked precision)	LR+ = (TP/(TP + FN)) / (FP/(FP + TN))
- Likelihood Ratio (LR-) (unlinked precision)	LR- = (FN/(TP + FN)) / (TN/(FP + TN))

This highlighted the various settings where certain thresholds may be more appropriate or necessary, such as during the investigation stage, or for the purposes of linking an offender to a series of crimes (where forensic evidence may be lacking), in order to arrest or convict them (Ewanation, 2023). Once all data were appropriately analysed, recommendations for guidelines were generated through an integration of the existing literature and the results of the data collection and analysis.

3.6 ETHICAL CONSIDERATIONS

After ethical approval was granted by HREC WITS and the SAPS, the researcher identified further significant ethical considerations during the course of the research, particularly regarding the researcher's role and the potential impact on the research. These additional considerations are listed below, together with the action taken on behalf of the researcher to address these issues.

3.6.1 Professional Conduct

3.6.1.1 Multiple Relationships

As the researcher is a Clinical Psychologist employed by the Department of Correctional Services, it was possible that the researcher could come into contact, or be in contact, with some of the serial murder offenders' cases used in this study. Due to the researcher's ethical obligations to the Health Professions Council of South Africa (HPCSA, 2004) code of conduct in limiting multiple relationships, as well as protecting the rights of her clients in terms of confidentiality, cases pertaining to any of the serial murderers incarcerated at the Correctional Centre with whom the researcher had a therapeutic relationship, were not included in the study. Fortunately, this did not occur. However, the researcher was mindful of this possible ethical dilemma during the data collection phase. Despite this, it is important to again reiterate that the research study did not require personal information about the offender, as it is not about the individual offender, but the behaviours exhibited at the crime scenes across series.

3.6.1.2 Personal Impairment

In addition to the awareness of possible conflicting, or multiple relationships, the researcher was further aware and mindful of the distressing content analysed for this study, also known as Emotionally Demanding Research (EDR). EDR is referred to research which is often on sensitive topics, such as examining crime scene and post-mortem photographic material of serial murder victims in the current study. EDR can be emotionally, mentally, and physically demanding and could possibly negatively impact the researcher (Burrell *et al*., 2023). Burrell *et al*. (2023) posited that not only can the topic itself be distressing, but external factors such as COVID-19, power outages, personal or familial illness, time and financial constraints of the researcher to conduct this study, could also negatively impact the researcher, and

compound the demands on the researcher. This matter was particularly relevant to the researcher, as this could have impacted on what the HPCSA refer to as 'personal impairment' (HPCSA, 2004) of psychologists, and thereby negatively affected the professional compliance of the researcher as a clinical psychologist. Ways in which the researcher addressed this issue was to seek supervision and supportive therapy when needed, taking regular breaks when feeling overwhelmed, and utilised her support network (Smillie & Riddell, 2023).

3.6.2 Confidentiality and Anonymity

Regarding the relatively small and identifiable population under consideration, the researcher complied with the *Protection of Personal Information Act (POPIA) No 4 of 2013* (South African Government, 2013) at all times. This Act highlights the obligations of an individual to: (a) only collect personal information that one needs for a specific purpose; (b) apply reasonable security measures to protect the data; (c) ensure that the data are relevant and updated if required; (d) only store what is necessary and applicable, and only for as long as one needs it; and (e) allow the relevant individual (subject of the information) to see the information upon request. Data was anonymised, collected, and stored on an encrypted USB file and kept securely by the researcher. All data was kept securely according to the ethical guidelines of the American Psychological Association (APA, 2016). The anonymised raw data will be kept for a minimum of six years to ensure the replicability of the study.

In addition to the above, to maintain confidentiality and anonymity, only aggregate data were reported on (Sorochinski *et al*., 2015). Identifiable features for example, the town or specifics of the victims were not reported. To further secure anonymity, only a copy of the results submitted for submission to the University is available to SAPS. Individual cases and secondary data analysis (raw data) done by the researcher will not be disclosed, to maintain anonymity. However, it is possible to keep the final and publishable results anonymous, as South Africa have experienced over 170 murder series since 1996 (Labuschagne, 2021). Therefore, there are hundreds of (often unknown/unidentified) victims, which dilutes the identities of cases as well as victims. In addition, not all the murder series have been commented on in the media.

3.6.3 Legal Implications

Due to the 'hearsay evidence' rule in the *Law of Evidence Amendment Act 45 of 1988* (South African Government, 1998), for the raw data and information gathered from the study to be used in court, the researcher would have had to be subpoenaed to court, forced by court order to reveal which series were used in the study, and be forced to give her opinion on the matter - the likelihood of a prosecutor doing this was, and is, extremely unlikely. Murder series included in the study remained anonymised in the research findings and only aggregated data is presented. As a result, it is not known which cases were reported on or utilised in the final report. However, information used in the study is information already available to SAPS as cases which have already been linked forensically, with an unknown suspect/ offender (and solved and convicted cases). Therefore, the implication that the research could be used to influence current or future investigations or legal proceedings in respect of any cases included in the study, was not applicable.

In terms of appeals, for the convicted offenders, no new evidence can be submitted to court during an appeal process. In addition, consistent with a positivist approach, this study employed a quantitative research design to determine whether behaviour consistency exists among serial murder offenders in South Africa. In other words, the purpose of the study was not to identify or make any inferences on who the suspect or offender may be, nor their possible motivations, connection to other crimes, or generalise the crime scene behaviours to the rest of the population of serial murder offenders (Davidson & Petherick, 2021; Park *et al.*, 2020).

3.7 FUNDING

The study was self-funded.

3.8 CHAPTER CONCLUSION

This chapter provided an overview of the research methodology and procedures used in the study. The chapter began by presenting the outline of the research design and methodology implemented. A description of the sample was provided, followed by an explanation of the research procedure, which included the data collection and statistical analysis procedures. Issues regarding quality and reliability of data were addressed, as well as how interrater reliability, and ecological validity were established. Lastly, the researcher described how

ethical and legal issues were addressed. The following chapter will present the results of the research with the chosen methodology to analyse the data and test the underlying hypotheses of offender's behavioural consistency and distinctiveness.

CHAPTER 4: RESULTS

4.1 CHAPTER PREVIEW

This chapter begins with the descriptive statistics of the sample followed by a breakdown of each variable per behavioural domain with accompanying frequency tables, comparing solved and unsolved crime series. Results from the statistical analysis are provided with corresponding number of B-LINK pairs, results of the Mann Whitney *U* tests, binary logistic regression analysis, and the accompanying ROC and AUC results. Thereafter, a contingency table demonstrates the different sets of outcomes as a result of the application of different thresholds.

4.2 DESCRIPTIVE STATISTICS

One hundred and twenty-six (126) victims were identified from 21 murder series (Mode = 4; Median = 4; M = 6, SD = 5.69) committed between 1999 and 2021. Within the total sample, 63% (n = 79) of victims resulted from 11 solved murder series (Mode = 4; Median = 4; M = 7.18, SD = 7.61). While 37% (n = 47) victims resulted from 10 different unsolved murder series (Mode = 3; Median = 4.5; M = 4.7, SD = 2.0). In the sample, solved murders series crimes were committed between 2004 and 2017, with a minimum of two murders and a maximum of 23 murders in a series. Unsolved murder series were committed between 1999 and 2021, with a minimum of two murders and a maximum of eight murders in a series. From the 10 unsolved murder series, 40% (n = 4) were first identified through DNA/forensic evidence, while 40% (n = 4) of the series were linked first through MO, and then DNA/forensic evidence. It was unknown whether cases were first linked through MO, or forensic/DNA evidence in 20% of unsolved cases (n = 2).

4.2.1 Target Selection Behavioural Domain

From the whole sample (solved and unsolved), almost 90% of victims were female (89.68%; n = 113), while 7.94% (n = 10) were male. Three (2,38%) of the recorded cases did not identify the sex of the victim as a result of badly decomposed bodies or bodies which were badly burnt. Seventeen (80,95%) offenders displayed complete consistency with regard to the gender of their victims. Only one series had all male victims. Of all the 126 victims, 104 (82,54%) victims were Black, 11 (8,73%) were Coloured, 10 (7,94%) were White, and one

(0,79%) victim was Indian. **Figure 4.1** below provides a visual summary of the total number of victims with regard to gender and race per solved and unsolved series.

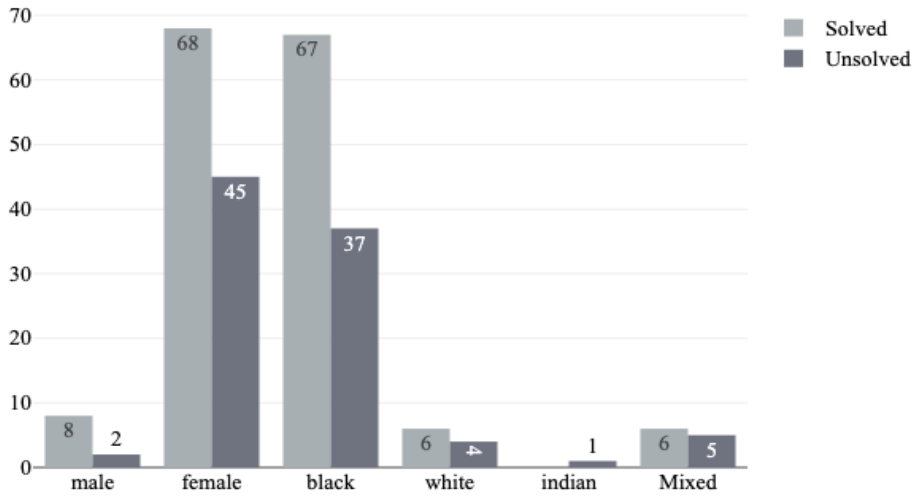


Figure 4.1 Total number of victims per gender and race categories in solved and unsolved series.

In terms of the age group, 11 offenders (52,38%) displayed complete consistency in the age range of the victims they murdered, but this decreased to eight (38,10%) offenders when surviving victims were included in ages of the victims targeted. A total of 57 (45,24%) of the victims fell within the 'adult' age group of 18-64 years old. As the victim's specific age was not known in many of the cases, having an 'adult' category mitigated this limitation. The second highest crime recording was for the age group of 13-17 years old with a total of 20 (15,87%) victims, whereas 17 (13,49%) victims were 65 years or older. Fifteen (11,90%) victims were 4-8 years old; 11 (8,73%) victims were 9-12 years old; and three (2,38%) victims were 0-3 years old. **Figure 4.2** provides a visual summary of victims age group. Overall, there is a higher chance the victim will be an adult female from the Black population, which was consistent between both solved and unsolved murder series.

In terms of victim's nationality, a total of 30 (23,81%) victims were recorded to be South African, five (4,76%) were identified as foreigners, and a total of 91 (72,22%) victim's nationality was not specified. Sixteen (53,33%) of the 30 known South African nationals' cases were solved, and two (40%) of the five known foreign nationals' cases were solved.

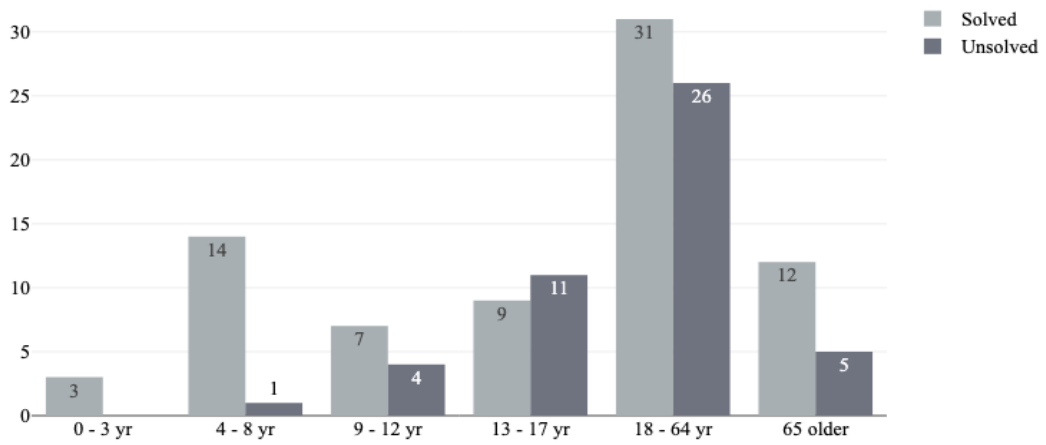


Figure 4.2 Total number of victims per age category in solved and unsolved series.

A total of 103 victims (81,75%) were murdered and 23 (18,25%) victims survived. A breakdown of victims for solved and unsolved series is seen in **Figure 4.3** below. Thirteen offenders (62%) murdered all of the victims in their series. Of the 103 murder victims, 62 (60,19%) of the cases were solved and 41 (39,81%) were unsolved. Of all the cases recorded, the victims were alone in 87 (69,05%) cases. Additionally, of these 87 cases where victims were alone, 51 (58,62%) cases were solved, whereas 36 (41,37%) cases were unsolved. One victim who survived an attempted murder and rape, was later murdered in the same (solved) series. This is the only identified case of this type of occurrence in the sample.

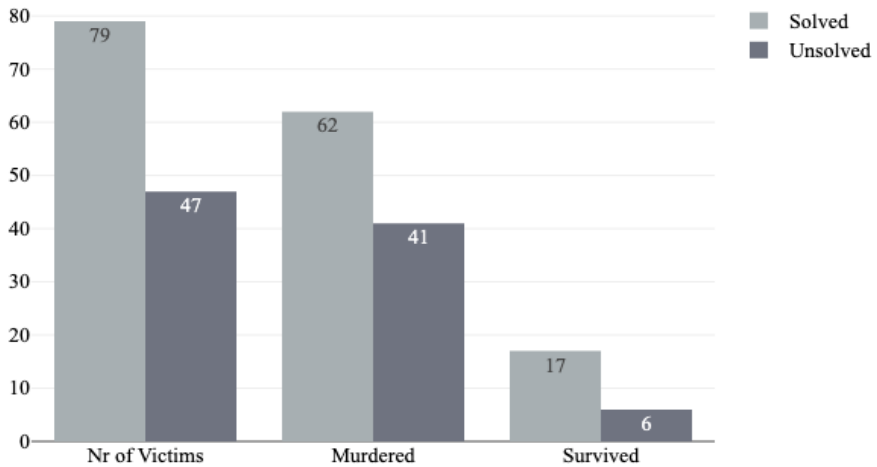


Figure 4.3 Total number of victims and survival outcome per solved and unsolved series.

Sixty-four (50,79%) cases identified how the victims were approached. Of the 64 known methods in which the victim was approached, 39 (30,95%) victims were approached within their residence, 18 (14,29%) were approached from the road/street, three (2,38%) victims were reportedly approached from the offender in a vehicle, three (2,38%) victims were approached/taken from open grounds/bushveld, and one (0,79%) victim was approached at work. The remaining 62 (49,21%) cases had missing information regarding how the victims were approached.

Looking at victim's employment status, a total of 14 (11,11%) victims were known to be employed, of which six (4,76%) of these victims were identified as sex workers, and eight (6,35%) victims were recorded as 'other' employment. From the sample, there is a higher chance that a murder of a sex worker will be unsolved. A total of 48 (38,10%) victims were scholars or of school-going age, and 17 (13,49%) were pensioners. The remaining 47 (37,30%) victims were either unemployed or their employment status was not known.

As the unsolved cases have not yet identified a perpetrator, there is missing/unknown information regarding the relationship between the victim and offender for unsolved cases. Therefore, a total of five victims (3,97%) were known to the offender from the solved cases. In total, one (0,79%) victim was an ex/romantic partner to an offender, one (0,79%) victim was known to be related to the offender, one victim (0,79%) was reported to be a colleague, and two (1,59%) victims were reportedly acquaintances/friends/neighbour to the offender (different series). **Table 4.1** below provides a comparison between solved and unsolved murder series with respect to frequency of occurrences within the target selection behavioural domain.

4.2.2 Sexual Behavioural Domain

When examining sexual behaviours, a condom was found in three (2,38%) of the crime scenes (one solved and two unsolved series). Eight (6,35%) victims were penetrated anally, whereas 44 (34,92%) victims were penetrated vaginally. Only one offender (4,76%) was consistent in penetrating (vaginally and anally) all the victims in the series. Two (1,59%) cases of digital penetration were reported, which were from the same (solved) murder series. In terms of non-lethal injuries to genitals, 19 (15,08%) victims exhibited injuries to their vagina, four (3,17%) showed injuries to their penis, and six (4,76%) victims had injuries

Table 4.1

Target Selection Domain Comparison between Solved and Unsolved Murder Series.

Target Selection Domain	Solved		Unsolved	
	n	**%**	***n***	**%**
Victim murdered	62	78.42%	41	87.23%
Victim Alone	51	64.56%	36	76.60%
Female victim	68	86.08%	45	95.74%
Black victim	67	84.81%	37	78.72%
White victim	6	4.59%	4	8.51%
Indian victim	0	0%	1	2.13%
Coloured victim	6	7.59%	5	40.64%
0-3 years old	3	3.80%	0	0%
4-8 years old	14	17.72%	1	2.13%
9-12 years old	7	8.86%	4	8.51%
13-17 years old	9	11.39%	11	23.40%
18-64 years old	31	39.24%	26	55.32%
65 years and older	12	15.19%	5	10.64%
South African	16	20.25%	14	29.79%
Employed as sex worker	2	2.53%	4	8.51%
Employment other	5	6.33%	3	6.38%
Scholar/school going age	31	39.24%	17	36.17%
Pensioner	12	15.19%	5	10.64%
Approach location road/street	10	12.66%	8	17.02%
Approach location residence	34	43.14%	5	10.64%
Approach location car	0	0%	3	6.38%
Approach location victim’s work	1	1.27%	0	0%
Approach location bush/veld	3	3.80%	0	0%
Victim known to offender	5	6.33%	0	0%
Victim ex-partner of offender	1	1.27%	0	0%
Victim related to offender (family)	1	1.27%	0	0%
Victim friend/acquaintance/neighbour to offender	2	2.53%	0	0%
Victim colleague of offender	1	1.27%	0	0%

to their anus. Six (4,76%) victims had genital mutilation. One (0,79%) surviving victim was found with a foreign object inserted into their anus (rock attached to a piece of string), and one (0,79%) murdered victim from an unsolved series was found with a foreign object inside their vagina (an illegal substance). Eight (6,35%) victims were found with a foreign object inside their mouth (clothing/material).

In terms of the state of undress of murdered victims, 28 (22,22%) victims were discovered fully clothed, 15 (11,90%) victims were found completely naked, 32 (25,40%) victims were completely naked from the waist down, while two (1,59%) victims were completely naked from the waist up. Only one (0,79%) victim was completely naked but covered, six (4,76%) victims had their clothing pulled up to expose just their breasts, while 13 (10,32%) victims had their clothing pulled down exposing their genitals but still present on their legs. Four (3,17%) victims had their clothing pulled up to expose their breasts as well as their clothing pulled down exposing their genitals, but still on the victims' legs.

A total of six (4,76%) victims showed evidence of redress while eight (6,35%) victims were found with their legs spread. Five (62.50%) of the eight victims discovered with their legs spread were completely naked from the waist down, two (25%) victims were found completely naked, and one (12.50%) victim had their clothing pulled up to expose their breasts and their clothing pulled down on their legs. Five offenders (23,81%) displayed complete consistency with regard to the state of undress of their victims.

No seminal fluid was reported to be identified within the mouth or anus of any of the victims whereas there were 14 (11,11%) cases where seminal fluid was found within the vagina of victims. Fourteen (11,11%) victims had seminal fluid found at the scene of the crime (on lose clothing items/bedding found at the scene), three (2,38%) crime scenes identified seminal fluid on the clothing of the victim, and three scenes (2,38%) identified seminal fluid on the body of the victim (such as a thigh or back).

Eighteen (14.29%) victims were found with their underwear on, whereas the underwear was completely missing in 24 (19,05%) crime scenes. In three (2.38%) cases, the victim's underwear was used as a weapon (such as a ligature), all from the same murder series, but was not consistent with each victim. A total of 15 (11,90%) victims' underwear was off their body but found at the crime scene. Twelve (9,52%) victims' underwear was found still

partially on their body, such as around one of the victim's legs. Three offenders displayed complete consistency with regard to the status of the victim's underwear across crimes. **Table 4.2** below provides a comparison between the frequency of solved versus unsolved murder series with regard to the sexual behavioural domain.

Table 4.2

Comparison of Sexual Behaviours between Solved and Unsolved Murder Series.

Sexual Behaviours	**Solved**		**Unsolved**	
	n	**%**	***n***	**%**
Fully clothed	15	18.99%	13	27.66%
Completely naked	10	12.66%	5	10.64%
Completely naked waist down	12	15.19%	20	42.55%
Completely naked waist up	1	1.27%	1	2.13%
Clothing pulled up to expose breasts	2	2.53%	4	8.51%
Clothing pulled down but still on legs	11	13.92%	2	4.26%
Clothing pulled up to expose breasts and clothing pulled down	3	3.80%	1	2.13%
Completely naked but covered	1	1.27%	0	0%
Redressed	1	1.27%	5	10.64%
Legs spread	2	2.53%	6	12.77%
Underwear on body	12	15.19%	6	12.77%
Underwear at scene off body	9	11.39%	6	12.77%
Underwear partially on body	9	11.39%	3	6.38%
Underwear completely missing	9	11.39%	15	31.91%
Underwear on body used as weapon	0	0%	4	8.51%
Penetration anus	5	6.33%	3	6.38%
Penetration vagina	23	29.11%	21	44.68%
Semen found on victim's body	3	3.80%	0	0%
Semen found in victim's vagina	7	8.86%	7	14.89%
Semen found at crime scene	12	15.19%	2	4.26%
Injuries to victim's vagina	13	16.46%	6	12.77%
Injuries to victim's penis	4	5.06%	0	0%
Injuries victim's anus	5	6.33%	1	2.13%

Foreign object found in victim's anus	1	1.27%	0	0%
Foreign object found in victim's vagina	0	0%	1	2.13%
Foreign object found in victim's mouth	5	6.33%	3	6.38%
Condom found at crime scene	1	1.27%	2	4.26%
Victim's genitalia mutilated/dismembered	5	6.33%	1	2.13%
Digital penetration	2	2.53%	0	0%

4.2.3 Violence and Control Behavioural Domain

From the sample of 79 solved cases, nine (11,59%) cases had more than one offender, whereas the majority of the cases were committed by one offender (88,61%). In cases where there was more than one offender, all victims from the same offender were grouped to a series when they attacked in isolation as well as in combination with an additional offender(s). From the unsolved series, three surviving victims (from different series) reported that there was one offender involved in their attack. In addition, although DNA evidence (which forensically linked unsolved crimes to a series) matched only one offender's DNA in each murder series, it is still unknown whether there was another offender present during the crime or at the crime scene. Six offenders (28,57%) were consistent with their method of killing across crimes; of these, one (4,76%) offender was consistent with blunt force trauma as the Cause of Death (COD), one (4,76%) offender was consistent with COD as a result of a sharp object, three (14,29%) offenders were consistent with strangulation, and one (4,76%) offender was consistent in ligature strangulation. Fifteen (71.43%) offenders were inconsistent in their method of murdering the victim.

The COD was undetermined for 12 victims (11,65%). The most common cause of victims' death was by means of strangulation for 36 (28.57%) victims, with 16 (12,70%) resulting from ligature strangulation, eight (6,35%) caused by manual strangulation, and three (2,38%) cases which were caused by both ligature and manual strangulation. Nine (8,74%) cases stated COD as strangulation but did not specify whether COD was by ligature and/or manual strangulation. The second most common COD resulted from a sharp object of which there were 20 (15,87%) cases, with blunt force trauma in a total of 19 (15,08%) cases. No victim was killed by poisoning or by gunshot/s, and only one (0,79%) case of drowning was reported as the cause of death. A total of 11 (8,73%) victims died as a result of

suffocation/asphyxia, three (2,38%) died from burns, one (0,79%) victim died from a neck fracture, and six (4,76%) victims had COD due to 'multiple injuries' reported in the autopsy report.

In terms of weapons used by offenders, whether through inflicting injuries and/or COD (across all incidents - murder cases and surviving victim cases), a sharp object was the weapon used in 31 (24,60%) cases, ligatures were used in 21 (16,67%) cases, and hands accounted for 20 (15,87%) of the cases. There was a total of nine (7,14%) cases in which blunt objects were used as weapons and, 'multiple weapons' were known to be used in four (3,17%) cases. There were no non-lethal gunshot injuries however, a firearm was reported to be present at the scene in two (1,59%) cases. One witness had reported seeing a firearm, and one surviving victim reported seeing a firearm to police investigators. Seven (33,33%) offenders displayed consistency in terms of the injuries to murdered victims across crime scenes, which decreased to six (28,57%) offenders when all (including surviving) victims were included.

In terms of restraining victims, restraining of the victim's hands was most common with a total of 18 (14,29%) cases. Thirteen (10,32%) victims had their hands restrained behind their body, and three (2,38%) victims had their hands restrained above their head (victim lying on the ground). No cases identified where the victims had their hands restrained in front of them. Thirteen victims (10,32%) were found with their feet tied, and two (1,59%) victims were restrained at their knees. One (0,79%) victim was blindfolded while eight (6,35%) victims were gagged (with clothing/material). One offender (4,76%) was consistent in restraining all of the victims' hands and one offender (4,76%) was consistent in gagging all of their victims.

In terms of bodily injuries, 52 (42,06%) victims had non-lethal bodily injuries. Assault from a blunt object was the highest, with a total of 27 (21,43%) cases. There were 20 (15,87%) victims who had non-lethal injuries from a sharp object, 18 (14,29%) victims had non-lethal fractures. One (0,79%) victim had non-lethal dismemberment (arm, genital and lips), and survived the attack. **Table 4.3** below provides a comparison between solved and unsolved murder series with respect to the violence and control domain variables.

Table 4.3

Comparison of Violence and Control Behaviours between Solved and Unsolved Series.

Violence and Control Behaviours	Solved		Unsolved	
	n	**%**	***n***	**%**
One offender	65	82.28%	3	6.38%
More than one offender	9	11.39%	*Not available*	
Cause of Death (COD) undetermined	10	12.66%	2	4.26%
COD strangulation	15	18.99%	21	44.68%
COD ligature strangulation	7	8.86%	9	13.15%
COD manual strangulation	6	7.9%	2	4.26%
COD ligature and Manual strangulation	1	1.27%	2	4.26%
COD sharp object	18	22.78%	2	4.26%
COD blunt force trauma	7	8.86%	12	25.53%
COD suffocation/asphyxiation	4	50.6%	7	14.89%
COD drowning	0	0%	1	2.13%
COD burnt	3	3.80%	0	0%
Multiple COD	2	2.53%	4	8.51%
COD neck fracture	1	1.27%	0	0%
Known sharp object used on victim	26	32.91%	5	10.64%
Known blunt object used on victim	5	6.33%	4	8.51%
Ligature/rope/material used on victim	10	12.66%	11	23.40%
Firearm presented to victim	0	0%	2	4.26%
Hands of offender used on victim as weapon	11	13.92%	9	19.15%
Multiple weapons used	2	2.53%	2	4.26%
Non-lethal assault blunt object	19	24.05%	8	17.02%
Non-lethal asphyxiation	4	5.06%	3	6.38%
Non-lethal sharp object	20	25.32%	0	0%
Non-lethal injuries to victim’s body	36	45.57%	17	36.17%
Non-lethal fractures to victim’s body	15	18.99%	3	6.38%
Dismemberment while victim was alive	1	1.27%	0	0%
Hands restrained	10	12.66%	8	17.02%
Hands restrained behind of body	6	7.59%	7	14.89%
Hands restrained above head	3	380%	0	0%

Victim's feet restrained	4	5.06%	9	19.15%
Victim's knees restrained	1	1.27%	1	2.13%
Victim gagged	5	6.33%	3	6.38%
Victim blindfold	0	0%	1	2.13%
Victim burnt while alive	0	0%	0	0%

4.2.4 Crime Scene Characteristics Behavioural Domain

Regarding the body recovery location of (murdered) victims, the majority of victim's bodies were recovered from open veld/ground in a total of 56 (54,36%) cases. Whereas a total of 45 (43,69%) victim's bodies were discovered in residential buildings. Only two (1,94%) victims' bodies were found in a body of water (river). In terms of body position, the highest number of murdered victims were found on their back in a total of 41 (32,54%) cases. Twenty-two (17,46%) victims were discovered on their stomach, and 14 (11,11%) victims were found on their side. One (0,79%) victim was discovered hanging/suspended from a pole. One (0,79%) victim from the solved murder series was discovered in the foetal position however, investigators deduced from the crime scene that they were found in this position after the body was thrown down a hill, and not specifically placed in that position. Two offenders (9,53%) were consistent in the position of the victim's bodies at all of their crime scenes.

The majority of the residential crime scenes showed forced entry at 21 (16,67%) crime scenes, with 13 (10,32%) exhibiting forced entry through the window, and eight (6,35%) cases displayed forced entry through the door. In addition, in nine of the crime scenes (7,14%), the rooms were in disarray. Eight (6,35%) victims were thrown from a vehicle, whereas the majority of victim's were known to be murdered at the crime scene where the body was recovered, which accounted for a total of 45 (35,71%) victims. Eight (6,35%) victims were dismembered, of which four (3,17%) victims had their genitals removed, two (1,59%) victims were decapitated, and two (1,59%) victims had a limb/s dismembered. One (4,76%) offender was consistent with removing all of their (male) victims' genitals.

Regarding items taken from the victim, a total of 46 (36,51%) cases reported known items stolen from the victim. It was more common for the victim's cell phone/jewellery and other

personal valuables to be taken, which occurred in 30 (24%) cases. Clothing was the second most common item to be taken, with a total of 12 (9,52%) of cases. A body part was taken in four (3,17%) cases and, lastly, money was the least common item known to be taken in a total of three (2,38%) cases identified.

With regard to concealment of victims' bodies, the majority of bodies were not covered or concealed, and these accounted for a total of 97 (76,98%) of the cases. A total of 11 (8,73%) of the victims' bodies were concealed, of which nine (7,14%) victims were fully covered, and two (1,59%) victims were buried. A total of seven (5,56%) victims were partially covered, of which one victim was completely covered except for their face, and two (1,59%) victims had only their face covered. One (0,79%) victim's upper half of their body was covered/concealed, and one victim's lower half of their body was covered.

No weapon was found at 95 (75,40%) of the crime scenes. However, of the weapons discovered at the crime scenes, most of the weapons found were ligatures, in a total of 19 (15,07%) crime scenes. Blunt objects accounted for four (5,56%) of the cases, and two (1,59%) sharp objects were found at the crime scene. Six (4,76%) victims' bodies were burnt. A comparison between solved and unsolved crime scene characteristics variables can be seen in **Table 4.4** below.

Table 4.4

Crime Scene Characteristics Behavioural Domain Comparison between Solved and Unsolved Murder Series.

Crime Scene Characteristics Variables	**Solved**		**Unsolved**	
	n	**%**	***n***	**%**
Body found in Urban area	18	22.78%	27	57.45%
Body found in open veld/open ground	40	50.63%	25	53.19%
Body found in building/residence	32	40.51%	13	27.66%
Body found in body of water	1	1.27%	1	2.13%
Forced entry	18	22.78%	3	6.38%
Forced entry door	8	10.13%	0	0%
Forced entry window	10	12.66%	3	6.38%
Room in disarray	6	7.59%	3	6.38%

Victim body found on stomach	10	12.66%	12	25.53%
Victim body found on back	23	29.11%	18	38.30%
Victim body found on side	11	13.92%	3	6.38%
Victim body found hanging/suspended	0	0%	1	2.13%
Victim body found in foetal position	1	2.27%	0	0%
Victim body concealed	7	8.86%	4	8.51%
Only victim's face exposed	1	1.27%	0	0%
Victim upper half of body exposed	1	1.27%	0	0%
Victim lower half of body exposed	1	1.27%	0	0%
Victim fully covered	7	8.86%	2	4.26%
Only victim's face concealed/covered	1	1.27%	1	2.13%
Victim found partially covered	4	5.06%	3	6.38%
Body completely buried	2	2.53%	0	0%
Victim's body dumped from vehicle	2	2.53%	6	12.77%
Victim killed at body recovery scene	35	44.30%	10	21.28%
Victim dismembered	8	10.13%	0	0%
Victim head dismembered	2	2.53%	0	0%
Victim's limbs dismembered	2	2.53%	0	0%
Victim's genitals dismembered	4	5.06%	0	0%
No weapon found at scene	64	81.01%	31	65.96%
Sharp object found at scene	1	1.27%	1	2.13%
Blunt object found at scene	4	5.06%	3	6.38%
Ligature found at scene	10	12.66%	9	19.15%
Victim's body burnt	4	5.06%	2	4.26%
Victim's money stolen	1	1.27%	2	4.26%
Victim's items (jewellery/cell phone) stolen	18	22.78%	12	25.53%
Victim's clothing stolen	4	5.06%	8	17.02%
Victim's body part stolen	4	5.06%	0	0%

4.3 STATISTICAL ANALYSIS RESULTS

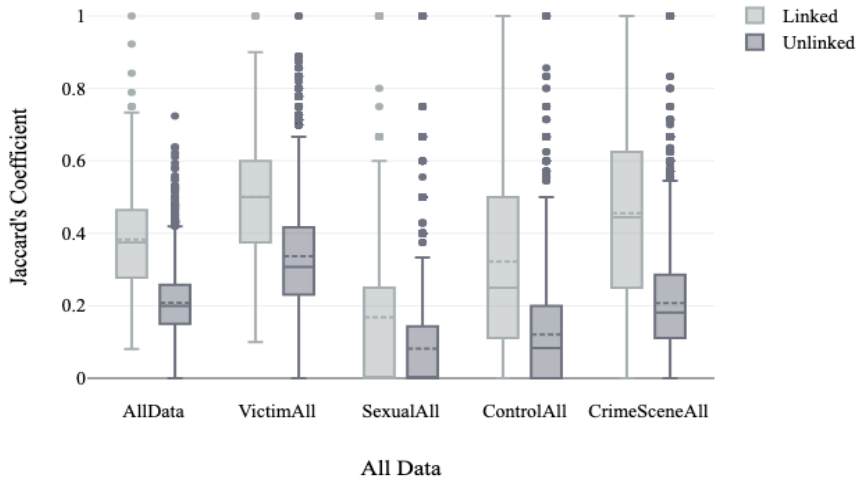
4.3.1 Determining Behavioural Similarity: Jaccard's Coefficient

When examining all the data (solved and unsolved), B-LINK produced Jaccard's similarity coefficients for a total of 7875 crime pairs (639 linked crime pairs and 7236 unlinked crime pairs). Solved murder series produced a total of 3081 crime pairs (534 linked crime pairs and 2547 unlinked crime pairs). Unsolved murder series produced a total of 1081 crime pairs (105 linked crime pairs and 976 unlinked crime pairs). **Figure 4.4** presents the boxplots for linked and unlinked crime pairs per data set.

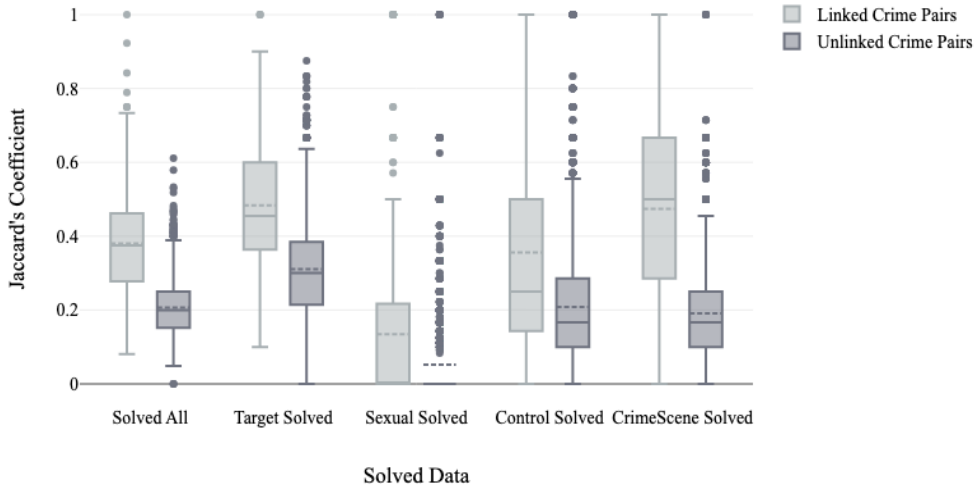
Jaccard's coefficient for all linked and unlinked crime pairs for each dataset were analysed and, in all datasets, Jaccard's coefficients for linked crime pairs were statistically higher ($p < .001$) than the corresponding Jaccard's coefficient for unlinked crime pairs, as seen in **Table 4.5.** This is strong evidence that linked crime pairs are indeed more behaviourally similar than unlinked crime pairs as the results mean that there is less than a 0.1% chance that this difference occurred through random chance. Effect sizes were calculated using the following formula: $r = \frac{z}{\sqrt{n}}$ (Pallant, 2020). Effect sizes ranged from 'weak' (r = 0.10) to 'moderate' (r = 0.48) (Cohen, 1962).

Overall, Jaccard's coefficient for *all* linked (all solved and all unsolved) crime pairs (Mdn = 0.38, SD = 0.14) was statistically higher than Jaccard's coefficient for *all* (all solved and all unsolved) unlinked crime pairs (Mdn = 0.21, SD = 0.08), with a moderate effect size (r =0.35) (Pallant, 2020). Jaccard's coefficient was also statistically higher for all *solved* linked crime pairs (Mdn = 0.38, SD = 0.14) than Jaccard's coefficient for all *solved* unlinked crime pairs (Mdn = 0.21, SD = 0.08), and demonstrated a moderate effect size (r = 0.48). Similar results were found for all *unsolved* linked Jaccard's coefficient crime pairs (M = 0.39, SD = 0.13) which were statistically higher than all Jaccard's coefficient for *unsolved* unlinked crime pairs Jaccard's coefficient (M = 0.22, SD = 0.08), and resulted in a moderate (r = 0.39) effect size (Pallant, 2020). The result means that there's less than a 0.1% chance that this difference occurred by random chance. This provides strong evidence that linked crimes are indeed more behaviourally similar than unlinked crime pairs.

A



B



C

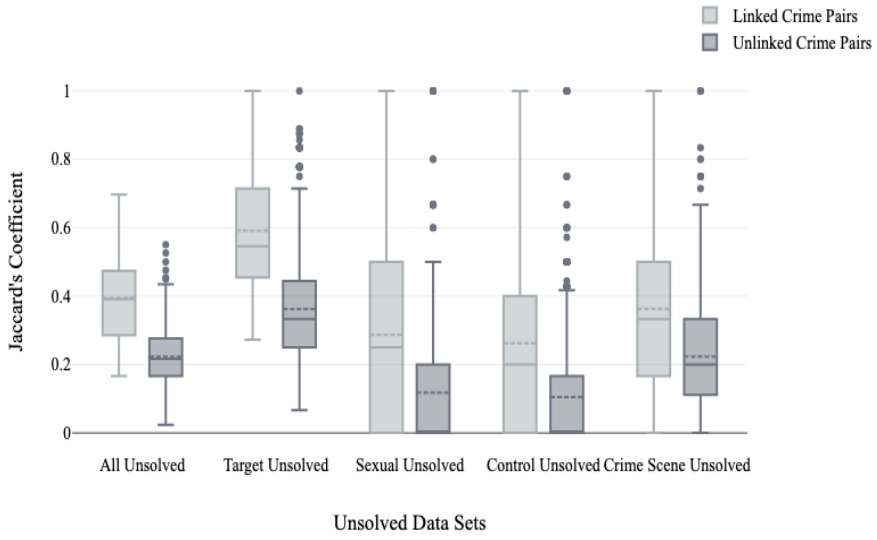


Figure 4.4 Boxplots of linked and unlinked crime pairs Jaccard's coefficients per A) all data (solved and unsolved); B) all solved data; C) all unsolved datasets.

Table 4.5

Statistical Comparison of Jaccard's Coefficient Between Linked and Unlinked Crime Pairs.

Domain/Variables	Crime Pairs	Jaccard's Mean (SD)	Jaccard's Median (Min. - Max.)	*U*	z	p	*r*
All Data	Linked	.38 (0.14)	.38 (.08 - 1.00)	615324	30.80	<.001	0.35
	Unlinked	.21 (0.08)	.20 (.00 - .72)				
All Solved Data	Linked	.38 (0.14)	.38 (.08 - 1.00)	182548.5	26.62	<.001	0.48
	Unlinked	.21 (0.08)	.20 (.00 - .61)				
All Unsolved Data	Linked	.39 (0.13)	.39 (.08 - 1.00)	12485	12.75	<.001	0.39
	Unlinked	.22 (0.08)	.22 (.02 - .55)				
Target Selection Behavioural Domain							
All Target Selection Variables	Linked	.50 (0.17)	.50 (.20 - 1.00)	1068828.5	22.59	<.001	0.25
	Unlinked	.34 (0.15)	.31 (.00 - 1.00)				
Solved Target Selection Variables	Linked	.48 (0.16)	.45 (.10 - 1.00)	280162	21.42	<.001	0.39
	Unlinked	.31 (0.14)	.30 (.00 - .88)				
Unsolved Target Selection Variables	Linked	.59 (0.18)	.55 (.27 - 1.00)	17327	11.17	<.001	0.34
	Unlinked	.36 (0.16)	.33 (.07 - 1.00)				
Sexual Behavioural Domain							
All Sexual Behaviours Variables	Linked	.17 (0.26)	.00 (.00 - 1.00)	1914096.5	8.93	<.001	0.10
	Unlinked	.08 (0.16)	.00 (.00 - 1.00)				
Solved Sexual Behaviours Variables	Linked	.13 (0.23)	.00 (.00 - 1.00)	546052.5	9.90	<.001	0.18
	Unlinked	.05 (0.13)	.00 (.00 - 1.00)				
Unsolved Sexual Behaviours Variables	Linked	.29 (0.28)	.25 (.00 - 1.00)	32833	0.66	<.001	0.20
	Unlinked	.12 (0.17)	.00 (.00 - 1.00)				
Violence and Control Behavioural Domain							
All Violence & Control Variables	Linked	.32 (0.29)	.25 (.00 - 1.00)	1286336.5	19.67	<.001	0.22
	Unlinked	.12 (0.15)	.09 (.00 - 1.00)				
Solved Violence & Control Variables	Linked	.36 (0.30)	.25 (.00 - 1.00)	480681	10.73	<.001	0.19
	Unlinked	.21 (0.18)	.17 (.00 - 1.00)				
Unsolved Violence & Control Variables	Linked	.26 (0.31)	.20 (.00 - 1.00)	37190	5.10	<.001	0.15
	Unlinked	.10 (0.16)	.00 (.00 - 1.00)				
Crime Scene Characteristics Behavioural Domain							
All Crime Scene Characteristics Variables	Linked	.46 (0.25)	.44 (.00 - 1.00)	918342	25.36	<.001	0.29
	Unlinked	.21 (0.16)	.18 (.00 - 1.00)				
Solved Crime Scene Characteristics Variables	Linked	.47 (0.25)	.50 (.00 - 1.00)	217925	24.77	<.001	0.45
	Unlinked	.19 (0.15)	.17 (.00 - 1.00)				
Unsolved Crime Scene Characteristics Variables	Linked	.36 (0.23)	.33 (.00 - 1.00)	32522.5	6.17	<.001	0.19
	Unlinked	.22 (0.16)	.20 (.00 - 1.00)				

4.3.2 Predicting Linked Status of Crime Pairs: Logistic Regression and LOOCV

Binary logistic regression analysis was performed on each data set to determine the influence of Jaccard's coefficient on the model, in order to predict the linked status of a crime pair. Binary logistic regression analysis demonstrated that the model was significant for all data (x^2 (1) = 1443.81, p < .001, n = 7875); all solved data (x^2 (1) = 1024.39, p < .001, n = 3081); as well as for all unsolved data (x^2 (1) = 239.8, p < .001, n = 1081). These consistent findings across datasets demonstrate that Jaccard's coefficient serves as a significant predictor of crime pair status, as the results mean that there is less than a 0.1% chance that this difference occurred through random chance, offering a substantially improved model fit. The logistic regression results for all datasets are displayed in **Table 4.6** below.

4.3.3 Accuracy of Linked Predictions: ROC Analysis and AUC Values

To assess the accuracy of the linked predictions, ROC analysis was conducted using the predicted probabilities produced from the LOOCV, to assess the discrimination accuracy of the linked status' of crime pairs (Burrell *et al*., 2024; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). The model aimed to classify serial murder cases based on the linkage status (0 = unlinked; 1= linked) of a crime pair, with the corresponding Jaccard's coefficient. As mentioned in the previous chapter, the AUC provides the *overall* level of discrimination accuracy based on the input probabilities from the ROC. This means that, if a model is effective, it is able to discriminate between linked crime pairs and unlinked crime pairs, indicating that an offender's behaviour is unique and distinct. Notably, the AUC value does *not* indicate how many times a correct link is made, it is a *relative* measure of linkage accuracy (Ewanation *et al*., 2023).

4.3.3.1 Discrimination Accuracy for All MO Behaviours

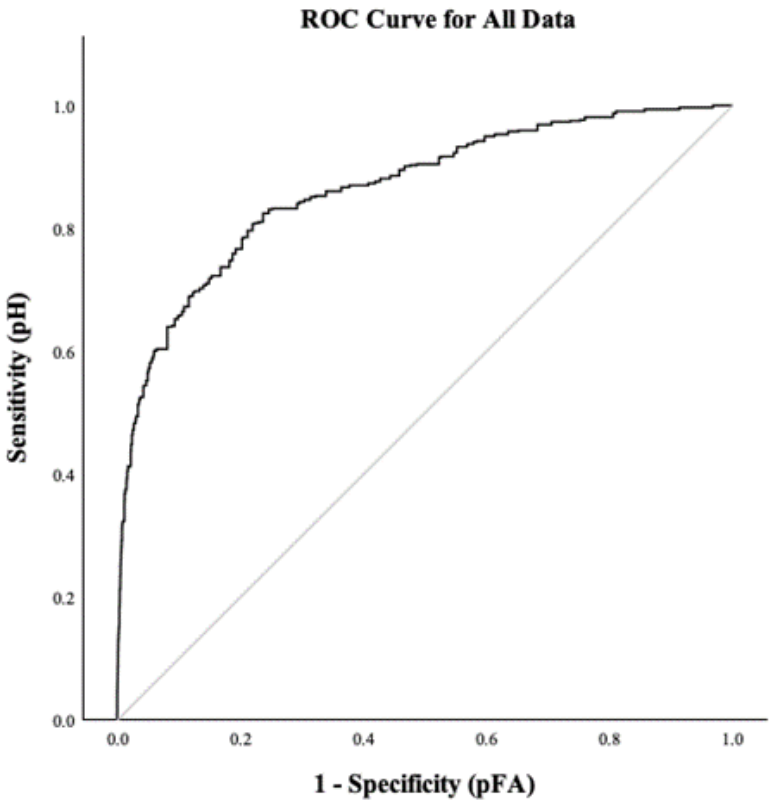
When all crime scene behaviours (MO) were considered (all behavioural variables), there was 'excellent' discrimination accuracy for all the data (solved and unsolved), as well as for all solved and all unsolved datasets. Full ROC and PRC are illustrated for all data (AUC = 0.87) in **Figure 4.5**; all solved data (AUC = 0.86) in **Figure 4.6**; and all unsolved data (AUC = 0.88) in **Figure 4.7.** The AUC is a relative measurement of linkage accuracy (Ewanation *et al*., 2023). In other words, the AUC value of .87 for all data indicates the probability that a randomly selected pair of crimes committed by the same offender will have higher across

Table 4.6

Results of Logistic Regression per Data Set.

Model	***x²* (*df*)**	Rn^2	**Constant *(SE)***	**B *(SE)***	**Wald *(df)***	**Exp (B)**
All Data	1443.81 (1) *	0.39	-6.77 (0.17)	15.49 (0.52)	903.57 (1)	5332933.42
All Solved Data	1024.39 (1) *	0.47	-6.13 (2.17)	16.48 (0.70)	549.86 (1)	14334385.80
All Unsolved Data	239.81 (1) *	0.42	-7.19 (0.48)	16.69 (1.40)	142.49 (1)	17845936.00
All Target Selection Behaviours	540.91 (1) *	0.15	-4.69 (0.12)	5.49 (0.24)	513.79 (1)	241.50
Solved Target Selection Behaviours	510.38 (1) *	0.25	-4.30 (0.16)	7.03 (0.35)	406.95 (1)	1124.26
Unsolved Target Selection Behaviours	134.51 (1) *	0.25	-5.13 (0.33)	6.21 (0.58)	115.21 (1)	498.89
All Sexual Behaviours	110.24 (1) *	0.03	-2.66 (0.049)	2.09 (0.19)	128.38 (1)	8.14
Solved Sexual Behaviours	98.59 (1) *	0.05	-1.78 (0.06)	2.59 (0.26)	99.97 (1)	13.32
Unsolved Sexual Behaviours	57.78 (1) *	0.11	-2.86 (0.15)	3.35 (0.44)	59.45 (1)	28.54
All Violence and Control Behaviours	537.86 (1) *	0.15	-3.278 (0.06)	4.01 (0.17)	531.24 (1)	54.93
Solved Violence and Control Behaviours	184.04 (1) *	0.10	-2.31 (0.08)	2.74 (0.20)	181.17 (1)	15.48
Unsolved Violence and Control Behaviours	49.34 (1) *	0.10	-2.74 (0.14)	3.04 (0.42)	52.43 (1)	20.90
All Crime Scene Characteristics	864.32 (1) *	0.24	-4.23 (0.09)	5.82 (0.22)	720.11 (1)	336.30
Solved Crime Scene Characteristics	787.63 (1) *	0.37	-3.70 (0.12)	7.02 (0.31)	514.22 (1)	1120.00
Unsolved Crime Scene Characteristics	52.26 (1) *	0.10	-3.30 (0.20)	3.77 (0.52)	52.091 (1)	43.49

* Note: $p < 0.001$



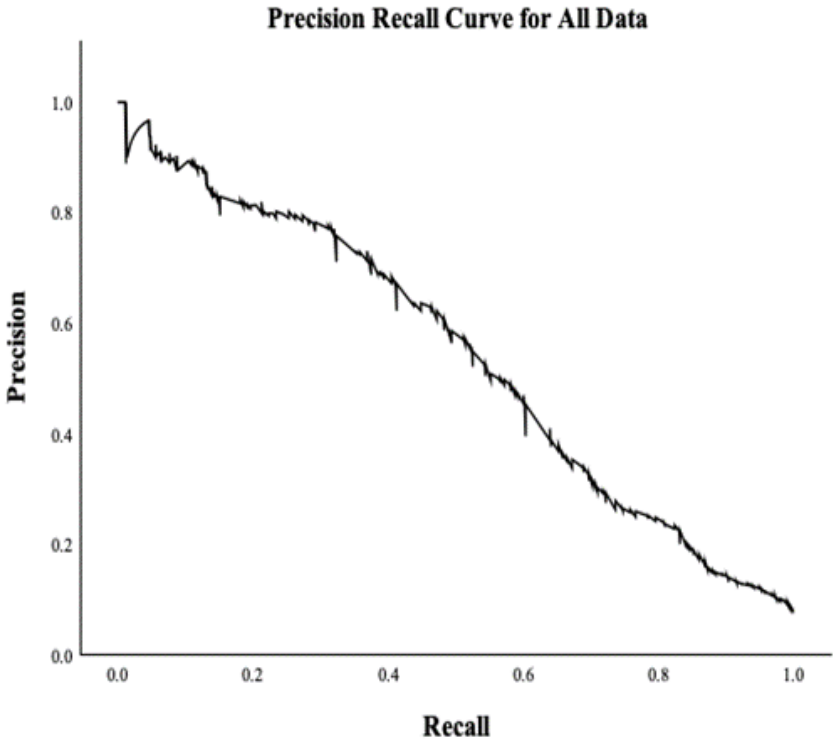


Figure 4.5 ROC and PRC for all data: AUC .87 ($p < .001$, SE = 0.1, 95% CI = .85 - .88).

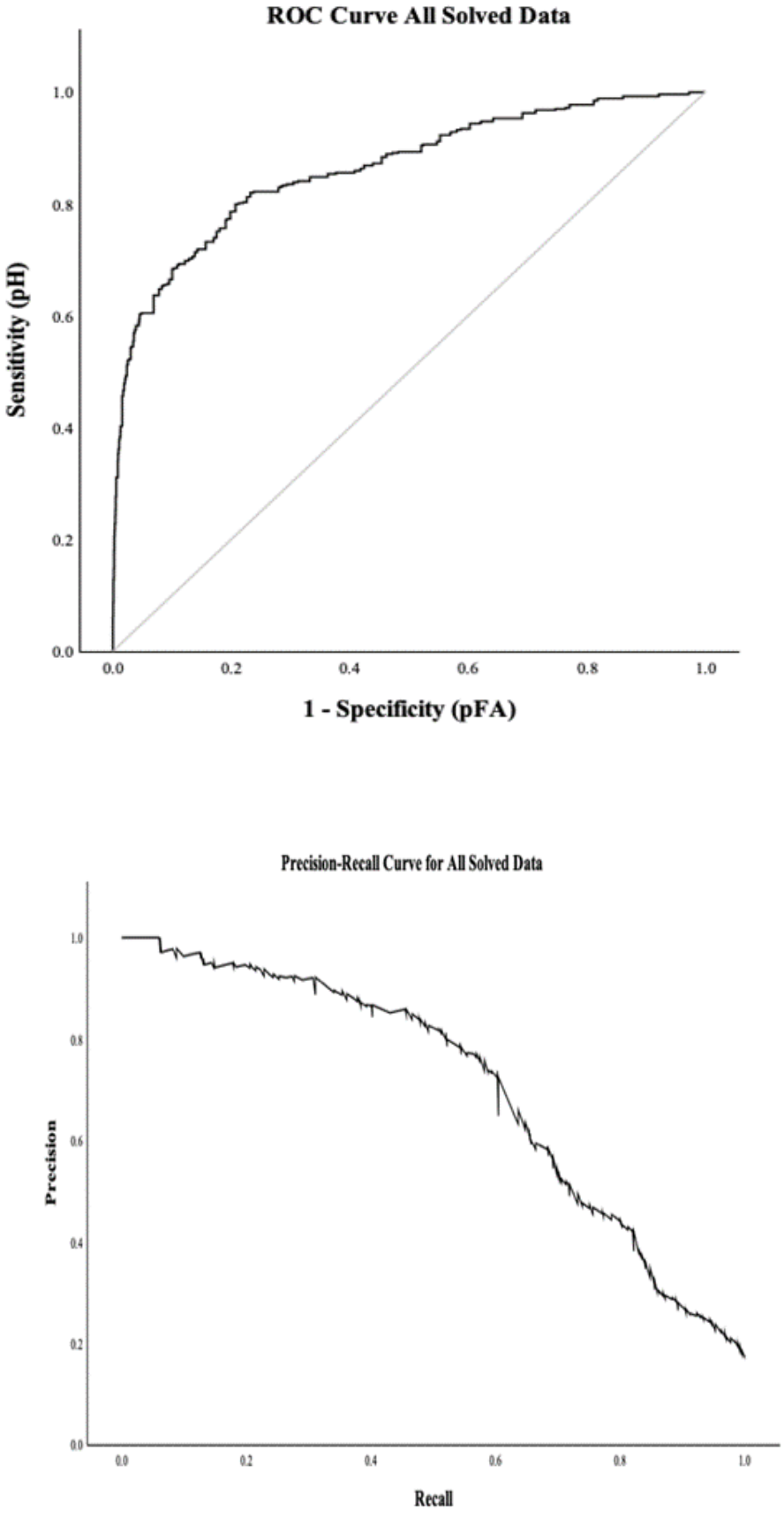


Figure 4.6 ROC and PRC for all solved data AUC .86 ($p < .001$, SE = .01, 95% CI = .85 - .88).

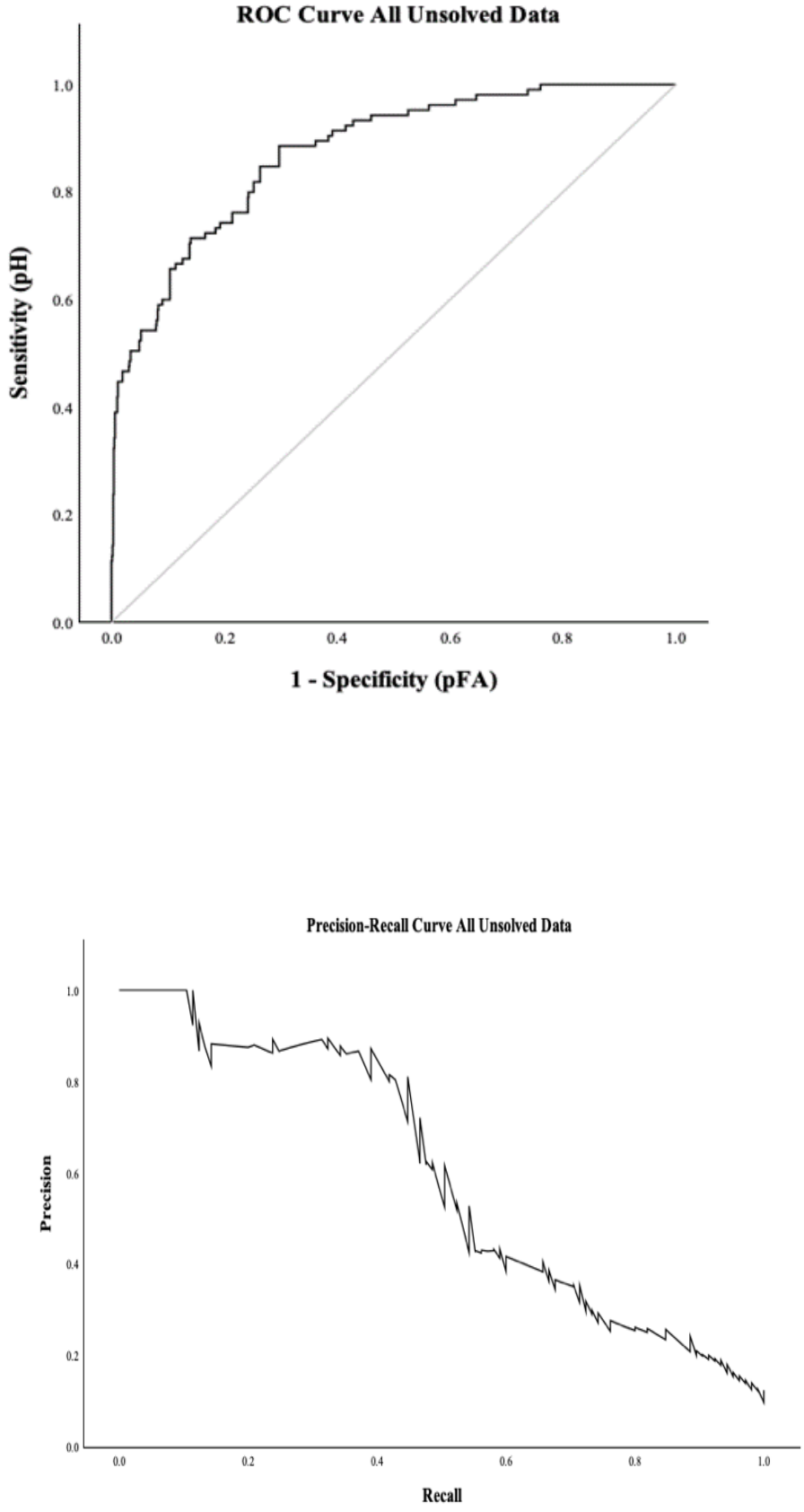


Figure 4.7 ROC and PRC for all unsolved data AUC .88 ($p < .001$, SE = .02, 95% CI = .84 - .91).

crime similarity scores 87% of the time when compared to a randomly selected set of crimes committed by different offenders (Ewanation *et al*., 2023). In other words, this provides support for the consistency and distinctiveness hypothesis of crime linkage using serial murder offender's behaviours. The results of the ROC AUC per dataset when examining all crime scene MO behaviours is provided in **Table 4.7** below.

Table 4.7

Results of ROC AUC for All Datasets.

Dataset	Area Under the Curve (*SE*)	95% Confidence Interval
All Data[a]	.87 (.01) *	.85 - .88
All Solved Data[b]	.86 (.01) *	.85 - .88
All Unsolved Data[c]	.88 (.02) *	.84 - .91

Notes. [a]Solved and unsolved offences (linked pairs n = 639, unlinked pairs n = 7236)
[b]Solved offences (linked pairs n = 534, unlinked pairs n = 2547)
[c]Unsolved offences (linked pairs n = 105, unlinked pairs n = 976).
* $p < 0.001$

For all data (solved and unsolved) AUC of .87 resulted in 'excellent' discrimination accuracy (Hosmer *et al*., 2013) and the model correctly classified cases 94% of the time. 'Excellent' discrimination was found in the AUC of .86 for all solved data and had a 90% correct classification of cases. 'Excellent' discrimination was also found for all unsolved data (AUC = 0.88), and cases were classified correctly 93% of the time. The AUC for all unsolved data was higher than all solved data however it was not statistically significant (D = 0.02, $p > 0.05$). Although there was also a difference between the AUC value for all data compared to the AUC for all solved data (D = 0.01) and compared to all unsolved data (D = 0.01), both were also not statistically significant ($p > 0.05$) (MedCalc, 2024).

4.3.3.2 Discrimination Accuracy per Functional Behavioural Domain

The result of the four functional domains varied between poor/no ability (AUC ≤ 0.50) for the model to discriminate between linked and unlinked crime pairs, to 'excellent' levels (AUC ≥ 0.80) of discrimination accuracy as seen in **Table 4.8**. 'Poor' levels of discrimination accuracy were displayed in all sexual behavioural domain (AUC = 0.37) and all violence and control behavioural domain (AUC = 0.66). The results indicated that the sexual behavioural domain and violence and control domain were ineffective in

discriminating between linked and unlinked crime pairs based on the predicted Jaccard's coefficient scores for each crime pair. Target selection domain displayed 'acceptable' levels of discrimination for all data (AUC = 0.75) and all solved data (AUC = 0.78). However, the model displayed 'excellent' discrimination accuracy for all unsolved target selection variables (AUC = 0.81). All data crime scene characteristics (AUC = 0.78) displayed 'acceptable' discrimination accuracy, 'excellent' discrimination accuracy for solved crime scene characteristics (AUC = 0.83). However, 'low' levels of discrimination accuracy were found for unsolved crime scene characteristics variables (AUC = 0.66), which was statistically different to all data crime scene characteristics (D = 0.12; $p < 0.001$).

Table 4.8

Summary of AUC Values for Functional Domain Datasets.

Functional Domain Datasets and Subsets	**AUC (*SE*)**	**95% CI**
Target Selection Domain		
All Target Selection Variables	.75 (.01) *	.74 - .77
Solved Target Selection Variables	.78 (.01) *	.76 - .80
Unsolved Target Selection Variables	.81 (.02) *	.78 - .85
Sexual Behaviour Domain		
All Sexual Behaviour Variables	.37 (.17) *	.01 - .41
Solved Sexual Behaviour Variables	.34 (.19) *	.30 - .34
Unsolved Sexual Behaviour Variables	.58 (.04) *	.50 - .66
Violence and Control Domain		
All Violence and Control Variables	.66 (.02) *	.63 - .69
Solved Violence and Control Variables	.61 (.02) *	.58 - .64
Unsolved Violence and Control Variables	.50 (.04) *	.42 - .59
Crime Scene Characteristics Domain		
All Crime Scene Characteristics Variables	.78 (.01) *	.76 - .80
Solved Crime Scene Characteristics Variables	.83 (.01) *	.80 - .85
Unsolved Crime Scene Characteristics Variables	.66 (.03) *	.60 - .72

* $p < 0.001$

Despite the target selection domain and crime scene characteristics domain displaying acceptable levels of discrimination accuracy (all data), the AUC for all data (AUC = 0.87) using all crime scene behaviours still outperformed both domains as seen in **Figure 4.8** below. As a result, due to the effectiveness of using all MO behaviours, decision thresholds were only applied to all MO data and not behavioural domains.

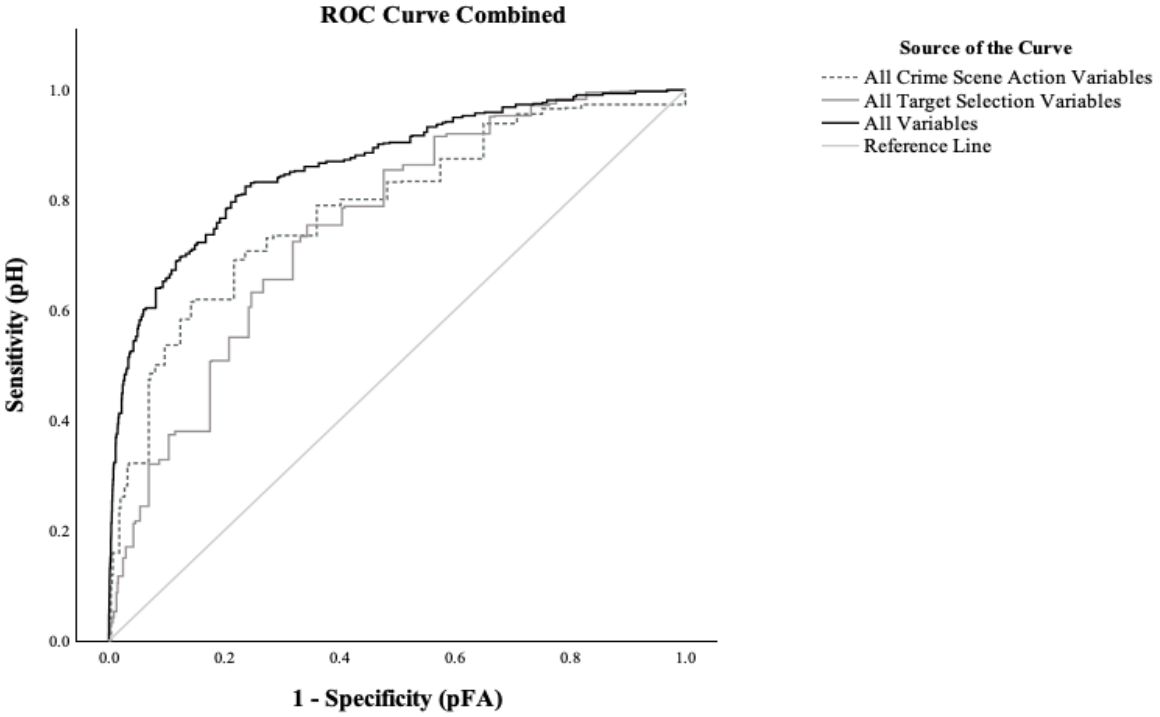


Figure 4.8 Comparison of Full ROC curves between All Data, All target selection variables, and all crime scene characteristics.
Note: All Data: AUC .87 (p<.001, SE=.01, 95% Cl=.85-.88).
All Target Selection Variables: AUC .75 (p<.001, SE=.01, 95% Cl=.74-.77).
All Crime Scene Characteristics Variables: AUC .78 (p<.001, SE=.01, 95% Cl=.76-.80).

4.4 Decision Thresholds

Different thresholds can be set to determine the number of 'hits' (predicted to be linked and actually linked), 'misses' (incorrectly predicted as unlinked when actually linked), 'false alarms' (incorrectly linked when actually unlinked) and 'correct rejections' (correctly predicting unlinked and in fact unlinked in reality). To display the effect of different thresholds, a contingency table for all data, all solved data, and all unsolved data, with corresponding results when four different thresholds were applied. A lenient threshold was set at a 90% true positive rate (hit rate) (pH). Youden's index was calculated to determine

which threshold maximises hits and minimises false alarms and was labelled as 'mid-range threshold', which is the point closest to the top left corner of the graph. A 'strict' threshold implemented a 15% False Alarm rate (pFA/1-specificity), and a 'very strict' threshold was set at a 5% False Alarm rate (pFA/1-specificity). The base rate for all data was 8.11%, while all solved data was 17.33% and all unsolved data was 9.71%. **Table 4.9** displays a summary of the outcomes when different decision thresholds were applied.

4.4.1 Lenient Threshold

When a 90% true positive rate was applied to demonstrate a lenient threshold ($pH \geq 0.90$), solved data had the highest false alarm rate of 53% with a corresponding Jaccard's coefficient of 0.20. All data had a 47% false alarm rate with a corresponding Jaccard's coefficient of 0.21. All unsolved data had the lowest false alarm rate of 38% and the highest Jaccard's coefficient of 0.24. As indicated by the Diagnostic Effectiveness (DE), the model correctly classified the linked status of crime pairs 56% of the time for all data; 55% of the time for all solved data crime pairs and, 64% of the time for all unsolved data crime pairs.

As indicated by the Misclassification Rate (MR), the model failed to classify crime pairs correctly 44% of the time for all data, 45% for all solved data and, 36% for all unsolved data. The Positive Predictive Value (PPV) is the probability that the linked crime pair was committed by the same offender (Ewanation *et al*., 2023) which was less than 15% for all data; 27% for all solved data; and 20% likelihood for all unsolved data. The probability that crimes which were unlinked and were likely to be committed by different offenders (as indicated by the Negative Predictive Value [NPV]), produced a 98% probability for all data, a 96% probability for all solved data and, a 95% likelihood for all unsolved data.

4.4.2 Mid-range Threshold

For all data, Youden's index ($J = 0.588$) identified a Jaccard's coefficient of 0.267, which resulted in a hit rate of 89.91% and, a false alarm rate of 22.94%. For all solved data, Youden's index ($J = 0.593$) corresponded with a Jaccard's coefficient of 0.267 which produced a hit rate of 79.96% and a 20.69% false alarm rate. For all unsolved data, Youden's index ($J = 0.561$) identified a Jaccard's coefficient of 0.261 which resulted in a hit rate (sensitivity) of 88.57% and a false alarm rate of 29.71%. The probability of crime pairs being

Table 4.9

Contingency Table of Decision Outcomes Across Thresholds.

		Predicted Linked Status					
		All Data		All Solved Data		All Unsolved Data	
Threshold	**Actual Linkage**	**Unlinked (0)**	**Linked (1)**	**Unlinked (0)**	**Linked (1)**	**Unlinked (0)**	**Linked (1)**
Lenient*	Unlinked (0)	3857 (CR)	3379 (FP)	1214 (CR)	1333 (FP)	601 (CR)	375 (FP)
	Linked (1)	63 (M)	576 (H)	51 (M)	483 (H)	11 (M)	94 (H)
Mid-range**	Unlinked (0)	5576 (CR)	1660 (FP)	2020 (CR)	527 (FP)	686 (CR)	290 (FP)
	Linked (1)	122 (M)	517 (H)	107 (M)	427 (H)	12 (M)	93 (H)
Strict***	Unlinked (0)	6131 (CR)	1105 (FP)	2182 (CR)	365 (FP)	826 (CR)	150 (FP)
	Linked (1)	178 (M)	461 (H)	150 (M)	384 (H)	30 (M)	75 (H)
Very Strict****	Unlinked (0)	6877 (CR)	359 (FP)	2420 (CR)	127 (FP)	928 (CR)	48 (FP)
	Linked (1)	277 (M)	362 (H)	211 (M)	323 (H)	50 (M)	55 (H)

Note: CR = Correct Rejections; FP = False Positive; M = Misses; H = Hits
All Data AUC .87 (p < 0.001, SE = .01, 95% CI = .85 - .88); All Solved Data AUC .86 (p<.001, SE=.01, 95% Cl=.85-.88); All Unsolved Data AUC .88 (p<.001, SE=.02, 95% Cl=.84-.91).
* Sensitivity = 0.9 (90% hit rate)
** Youden's Index (top left of graph)
*** 15% False Alarm Rate
**** 5% False Alarm Rate

committed by the same offender was less than 29% (PPV) for all data; 51% for all solved data and, 33% for all unsolved data. For all data and all unsolved data, there was a 97% probability (NPV) that unlinked crime pairs were likely to be committed by different offenders, whereas there was a 94% probability of this for all solved data.

4.4.3 Strict Threshold

When a false alarm rate of 15% was applied (pFA ≤ 0.15), there was a 72% hit rate for all data as well as all solved data, and a 71% hit rate for all unsolved data. The model correctly classified the linked status of crime pairs 84% (DE) of the time for all data; and 83% of the time for both solved and unsolved data. The model failed to correctly classify crime pairs 16% (MR) of the time for all data, and 17% of the time for both solved and unsolved data. There was a 29% (PPV) probability that predicted crime pairs were the work of the same offender for all data; 51% probability for all solved data and, 33% probability for all unsolved data. For all data and all unsolved data, there was a 97% probability (NPV) that unlinked crime pairs were likely to be committed by different offenders, whereas there was a 94% probability for all solved data. Corresponding Jaccard's coefficient was 0.290 for all data, 0.287 for all solved data and 0.306 for all unsolved data when a 15% false alarm rate was applied.

4.4.4 Very Strict Threshold

When a very strict threshold of 5% false alarm rate was applied (pFA ≤ 0.05), corresponding Jaccard's coefficient was highest for all unsolved data (0.37), followed by all data (0.35) and, then all solved data (0.34). There was a hit rate of 57% for all data, 61% for all solved data and, 52% for all unsolved data. The model correctly classified the linked status of crime pairs 92% (DE) of the time for all data; 89% for all solved data and, 91% for all unsolved data. The model failed to correctly classify crime pairs 8% (MR) of the time for all data, 11% for all solved data and, 9% for all unsolved data.

The probability of linked crime pairs being the work of the same offender was less than 50% (PPV) for all data; 72% for all solved data and 54% for all unsolved data. For all data there was a 96% probability (NPV) that the crimes that were unlinked, were likely to be committed by different offenders. Whereas there was a 92% probability for all solved data, and 95% probability for all unsolved data. The positive likelihood ratio (LR+) of 11.42 for all data,

12.13 for all solved data and, 10.65 for all unsolved data and corresponding low likelihood ratio of 0.46, 0.42 and, 0.50 respectively (LR-) suggests that there was ‘good’ discrimination accuracy for the model to distinguish between linked and unlinked crime pairs when a very strict threshold was applied (Grimes & Schulz, 2005).

4.5 CHAPTER CONCLUSION

This chapter provided the results of the descriptive statistics of the sample as well as a breakdown of each variable per behavioural domain, with further comparisons between solved and unsolved series. Results of the inferential statistics displayed significant differences in Jaccard’s coefficients for linked and unlinked crime pairs, indicating that linked crime pairs displayed more consistent and similar behaviours across crimes, than unlinked crime pairs. ROC curves displayed excellent discrimination when all MO behaviours were analysed, as opposed to the separate functional behavioural domains. Target selection and crime scene characteristics behavioural domains were more effective at discriminating between linked and unlinked crime pairs. However, sexual behaviours and violence and control behavioural domains were ineffective at discriminating between linked and unlinked crime pairs. A contingency table demonstrated the results of the models to predict linkage status when different thresholds were applied, which is important to consider at various stages of the investigation process and which will be discussed further in the following chapter.

CHAPTER 5: DISCUSSION

5.1 CHAPTER PREVIEW

This chapter presents a discussion of the findings from the results of the study. It begins by providing an overview of the key findings achieved through the research objectives, followed by an in-depth discussion of behaviour consistency and distinctiveness of serial murder offenders in South Africa. Effectiveness of linking crime pairs is tested through examining all behaviours, as well as functional behavioural domains, comparing solved and unsolved series. The chapter further explores performance outcomes through the application of different decision thresholds. Performance metrics indicate the outcomes of these thresholds and how they impact on sensitivity, specificity, and decision-making errors, which is applicable to the application of the logistic regression model for investigators. The chapter concludes by examining the usefulness and effectiveness of the study, and the resulting implication of the findings.

5.2 OVERVIEW OF KEY FINDINGS

Crime linkage has become an important investigative tool and has been used to link crimes effectively based on behavioural evidence displayed at the crime scenes, particularly when forensic evidence has not been available (Labuschagne, 2015b). Due to the serious implications, it is crucial that the reliability and validity of crime linkage is well researched and that the underlying principles of crime linkage are tested and examined internationally, as well as in South Africa. To date, no study has included unsolved murder series when testing the assumptions of crime linkage of serial murder offenders. As a result, this study set out to determine whether behaviour consistency and distinctiveness exists among solved and unsolved murder series using a sample of South African serial murder offenders. The sample consisted of 21 South African murder series, and a total of 126 victims were identified. Seventy-nine victims were linked to 11 solved murder series, and 47 victims were linked to 10 unsolved murder series. Including unsolved murder series increased the ecological validity of the study and addressed limitations of previous crime linkage research which were criticised regarding the samples which were used, as they only included solved crimes (Bennell & Jones, 2005; Pakkanen *et al*., 2021; Tonkin *et al*., 2012b; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a).

Through the context of the research objectives, this research empirically tests the underlying principles of crime linkage of South African serial murderers using quantitative analysis by determining behavioural similarity (consistency), and discrimination accuracy (distinctiveness). These findings were indicated by the findings of the Jaccard's similarity coefficient and discrimination accuracy of the ROC analysis and corresponding AUC value. Similarity of linked and unlinked crime pairs using Jaccard's coefficient indicate that offenders behave in similar ways across crimes, which provides support for the assumption of behaviour consistency (Bennell & Canter, 2002; Woodhams *et al*. 2019). To test discrimination accuracy, results of the binary logistic regression and ROC analysis indicate that high levels of predictive accuracy were achieved. An 'excellent' level of discrimination accuracy was found when all MO behaviours (solved and unsolved series) were examined (AUC = 0.87).

The results of the study correspond with similar discrimination accuracy (AUCs) of previous research studies conducted on serial murder offenders, which displayed 'excellent' discrimination accuracy among serial murder offenders in Italy (AUC = 0.88, Pakkanen *et al*., 2021), and 'outstanding' discrimination accuracy among serial murder offenders in the USA (AUC = 0.96, Melnyk *et al*., 2011). Overall support for the underlying assumptions of crime linkage was found in a sample of (solved and unsolved) South African murder series, as linked and unlinked crime pairs could be reliably linked, based on behaviour consistency and distinctiveness. This suggests that serial murder offenders display behaviour consistency and distinctiveness, across cultures, providing support for the assumptions of crime linkage.

Despite providing support for the assumptions of crime linkage when all crime scene behaviours were considered, results of the functional behavioural domains indicate variability in the data, which is consistent with findings from previous crime linkage studies and studies examining behaviour consistency of serial murderers (Bennell *et al*., 2021; Salfati *et al*., 2015a; Sorochinski & Salfati, 2010; Woodhams *et al*., 2019). The results of the study highlight the importance of examining behavioural consistency across functional behavioural domains by identifying domains with high discriminatory power, while acknowledging potential variability within and across domains (Woodhams & Labuschagne, 2012a). In other words, some offenders may display greater behavioural consistency and uniqueness in one functional behavioural domain, and not necessarily another, and for various reasons, elaborated on below.

While these reasons were not the focus of this study, the researcher provides speculative explanations. For example, findings of the current study suggest that behaviours such as target selection and crime scene characteristics, which are predominantly considered within the offender's planning and control, are more consistent, and corresponds with findings from previous research studies (Bennell *et al*., 2021; Sorochinski & Salfati, 2010). This could then suggest that behavioural domains such as sexual behaviours and violence and control behaviours display less consistency, as they are influenced by situational contexts such as the interaction with the victim (Salfati *et al*., 2015a; Salfati, 2019; Sorochinski *et al*., 2015). Therefore, these behaviours are considered less in control of the offender, as the offender cannot plan in advanced how the victim will react or external situational contexts in advance, such as an interruption of the crime by a witness, which consequently impact on the offender's behaviour (Sorochinski & Salfati, 2010).

Therefore, results of the study indicate that combining all MO behaviours is more effective at linking crimes, rather than individual functional behavioural domains. This finding corresponds with reports from previous crime linkage research, which found that a combination of all MO behaviours is more effective at linking crimes than individual themes or domains (Burrell *et al*., 2024; Tonkin, 2015). This study paves the way for future research and investigation into the behavioural characteristics of serial offenders, particularly regarding potential changes in behaviour across and between solved and unsolved murder series. The overall consistency and distinctiveness of serial murder offenders will first be explored when combining all crime scene behaviours, before a brief comparison between solved and unsolved series is presented.

5.3 INTERPRETATION OF FINDINGS

5.3.1 Overall Behaviour Consistency and Distinctiveness of Serial Murder Offenders in South Africa

The first objective of the study was to test the underlying principles of crime linkage namely, the similarity and distinctiveness of South African serial murder offenders' behaviour which included all behaviours and all (solved and unsolved) series. To determine behaviour similarity, the software program B-LINK calculated Jaccard's coefficient scores for each crime pair (Bennell & Canter, 2002). Kolmogorov-Smirnov test confirmed significant deviations ($p < .001$) from a normal distribution, necessitating the use of a non- parametric

test. Mann-Whitney *U* test confirmed that median Jaccard's similarity coefficient scores of linked crime pairs was significantly larger ($p < .001$) than unlinked crime pairs with a moderate effect size ($r = 0.35$) (Cohen, 1960). This suggests that offenders behave in similar ways across crimes, which indicates behaviour consistency.

This finding aligns with previous research studies which demonstrated that linked crime pairs displayed greater similarity than unlinked crime pairs (Bennell *et al*., 2014; Bennell & Canter, 2002; Tonkin *et al*., 2012b; Tonkin & Woodhams, 2017; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). Jaccard's coefficient scores for linked crime pairs (all data) had a minimum value of .08 and a maximum value of 1.00. The maximum value of 1.00 indicates that some linked crime pairs displayed perfect behavioural similarity (Bennell & Canter, 2002; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). Unlinked crime pairs (all data) minimum Jaccard's coefficient value of .00 indicates no similarity, and 0.72 was the maximum Jaccard's coefficient value for unlinked crime pairs. This indicates that no unlinked crime pair demonstrated perfect similarity and therefore, supports the assumption that linked crime pairs are more similar than unlinked crime pairs. This provides further support for one of the underlying principles of crime linkage, which is the behaviour consistency of offenders, which suggests that if offenders demonstrate behaviour similarity, then it is likely that they are consistent in the behaviours that they display across crimes (Bennell *et al*., 2021; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a).

To cross-validate the results and to ensure that they generalise beyond the data used to develop the regression model, the LOOCV method was applied to all datasets, mirroring previous crime linkage research (Tonkin *et al*., 2012b; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). Thereafter, to test discrimination accuracy, predicted probabilities obtained from Jaccard's coefficient as input in the LOOCV syntax, were used in a ROC analysis. Determining discrimination accuracy was necessary to test the second hypothesis underpinning crime linkage, which is that offenders are distinct and unique in their crime scene behaviours and, as a result, can be distinguished from one another (Woodhams *et al*., 2019). The model was able to distinguish between linked and unlinked crime pairs effectively and displayed 'excellent' discrimination accuracy (AUC = 0.87).

The AUC provides an overall indication of linkage accuracy. In other words, an AUC of .87 indicates that randomly selected linked crime pairs (crimes committed by the same offender)

will have higher similarity coefficient scores (predicted probabilities) 87% of the time than randomly selected unlinked crime pairs (crimes committed by different offenders) (Bennell *et al*., 2014; Ewanation *et al*., 2023; Pakkanen *et al*., 2021). The model correctly classified crime pairs 94% of the time (as indicated by the DE) and had a corresponding MR of 6%. This finding corresponds with results of previous research, which found high levels of linking accuracy among serial murder offenders (AUC = 0.88, Pakkanen *et al*., 2021; AUC = 0.96, Melnyk *et al*., 2011).

This finding demonstrates that overall, when all crime scene behaviours are included, South African serial murder offenders (solved and unsolved series) are consistent, and that linked crime pairs can be effectively distinguished from unlinked crime pairs, indicating distinctiveness of crime scene behaviours. This further supports the theory that when an offender finds what works for them to successfully commit the crime, and evade apprehension, their behaviours are often stable and consistent (Hazelwood & Warren, 2003; Woodhams & Labuschagne, 2012a). In addition, due to the internal fantasy and psychological meaning of the crime to the offender, their behaviours are often unique (Gee & Belofastov, 2015; Sorochinski & Salfati, 2010; Woodhams & Labuschagne, 2012a). The value of including an ecologically valid sample (unsolved series) strengthens the support for the assumptions of crime linkage. A comparison of similarity and distinctiveness between solved and unsolved series when examining all behaviours, will be explored further below.

5.3.1.1 Comparison of Behaviour Consistency and Distinctiveness Between Solved and Unsolved Murder Series

Mann Whitney *U* tests indicated that Jaccard coefficient linked crime pairs were significantly larger than Jaccard coefficient unlinked crime pairs, across solved and unsolved datasets when all behaviours were included. Moderate to moderate-to-strong effect sizes were found respectively. This suggests that, regardless of whether a series was solved or not, linked crime pairs displayed similar and therefore, consistent behaviour across series. This is an important finding as it addresses concerns of previous crime linkage research studies which only included solved series. It has been suggested that there may have been sample bias (Cooper & Meterko, 2019; Davies *et al*., 2019) in previous crime linkage studies. This is because researchers have speculated that unsolved series are possibly less similar, and less consistent, and therefore, more challenging for investigators to link and solve the series

(Bennell & Jones, 2005; Tonkin *et al*., 2012b; Woodhams & Labuschagne, 2012a). However, the finding of the study suggests that linked crime pairs, across solved and unsolved murder series, displayed greater behavioural consistency than unlinked crime pairs. This indicates that unsolved series linked crime pairs display behaviour similarity, as indicated by the linked crime pairs which were significantly more similar than the unlinked crime pairs. Although the effect sizes suggest that linked crime pairs from the solved series had a slightly larger effect than linked crime pairs from the unsolved series. This suggests that series which were solved displayed slightly higher levels of behaviour consistency than unsolved series.

High levels of linking accuracy were found, regardless of whether the series was solved or unsolved when all behaviours were included. Against expectation, unsolved series displayed slightly higher discrimination accuracy (AUC = 0.88) with a 93% accuracy at classifying linked and unlinked crime pairs. Whereas the solved series (AUC = 0.86) correctly classified crime pairs 90% of the time. This is an unexpected finding; however, it could be hypothesised that solved cases included cases which were linked through forensic means, or a confession, that may not have been linked otherwise. However, the difference between the solved and unsolved AUC values was not statistically different ($p > 0.05$). This finding is important for providing empirical support for the underlying principles of crime linkage research using an ecological valid sample.

This finding demonstrates that unsolved murder series also display behaviour consistency and distinctiveness, which has been subject to speculation, as previous research studies were criticised and limited by only utilising solved murder series (Bennell *et al*., 2021; Bennell & Jones, 2005; Santtila *et al*., 2008). This supports the notion that unsolved murder series are not always a result of a lack of inter-case linkage or failure to link related crimes, but rather that serial offenders often rely on chance and 'luck' to avoid detection (Yaksic *et al*., 2021; Yaksic, 2023). This is an interesting finding as it contrasts with findings from Woodhams and Labuschagne (2012a) and Woodhams *et al*. (2019) study, which examined serial sexual crimes and found slightly lower levels of discrimination accuracy of unsolved serial sexual offenders.

There are several possible explanations for this different outcome. Firstly, both studies conducted by Woodhams and Labuschagne (2012a) and Woodhams *et al*. (2019) were

examining serial rape and not murder series. Therefore, the variables used to capture behaviours are different and arguably not comparable or generalisable to other crime types. In addition, the researcher speculates that within the current study, many of the case files of unsolved series, especially those from the most recent years, were often more descriptive and had, for example, more detailed, and richer information compiled by the IPS. The richer the information and the more information gathered, can result in increased accuracy of crime linkage (Winter *et al*., 2013; Woodhams *et al*., 2019). Therefore, as highlighted in previous studies, the quality of the data used as input is important for the quality of the output of results (Bennell *et al*., 2021; Davies *et al*., 2021; Turvey & Freeman, 2012a; Woodhams & Davies, 2021).

However, the model's ability to effectively classify linked and unlinked crime pairs, regardless of whether the series was solved or unsolved, provides valuable insights regarding the consistency and distinctiveness of serial murder offending behaviour across crimes (Pakkanen *et al*., 2021). Understanding the potential differences between behaviour consistency between solved and unsolved murder series is crucial for understanding and improving crime linkage research, particularly in the context of unsolved murder series. If certain domains exhibit higher or lower AUCs for unsolved cases, this highlights the need for alternative investigative strategies that, in the absence of a clear suspect or a surviving victim, can capture more comprehensive and nuanced crime scene behavioural information (Bennell *et al*., 2021). Further examination of the functional behavioural domains will now be discussed in detail below.

5.3.2 Functional Behavioural Domain Effectiveness at Linking Crimes

If linked crime pairs display greater behavioural similarity, this suggests that they behave consistently (and similarly) across crimes. As indicated by Mann Whitney *U* test, all linked crime pairs Jaccard's coefficient scores were significantly larger ($p<.001$) than unlinked crime pairs Jaccard's coefficient scores across behavioural domains, and across solved and unsolved series. This further provides support for the underlying assumption of crime linkage with regard to behaviour consistency of offenders, as linked crime pairs are more similar in crime scene behaviours than unlinked crime pairs (Pakkanen *et al*., 2021; Woodhams *et al*., 2019). However, effect sizes were small and, based on Jaccard's coefficients, some crime pairs (both linked and unlinked crime pairs) reached perfect

similarity (as seen by the maximum Jaccard's coefficient score of "1"). The variability in the data suggests that some offenders may behave very consistently in some contexts (such as within the behavioural domains, and/or across crimes) however, in some cases, they may behave inconsistently which supports finding from previous research studies (Bateman & Salfati, 2007; Salfati & Bateman, 2005; Sorochinski & Salfati, 2010, 2019; Tonkin *et al*., 2019; Woodhams & Labuschagne, 2012a).

To ascertain behaviour distinctiveness through discrimination accuracy of the AUCs, a range of outcomes were demonstrated across the behavioural domains. Domains with higher AUC's demonstrate stronger discriminatory accuracy, meaning that they effectively differentiated between linked and unlinked crime pairs (Bennell & Canter, 2002). However, some domains were ineffective at discriminating between linked and unlinked crime pairs (AUC $\leq$ 0.5). This indicates that offender's behaviour in some behavioural domains are less distinct, and thus linked and unlinked crime pairs could not be differentiated from one another. This suggests that those individual functional behavioural domains are not useful for linking purposes.

Overall, when solved and unsolved series were combined *target selection* domain (AUC = 0.75) and *crime scene characteristics* domain (AUC = 0.78) displayed 'acceptable' levels of discrimination accuracy. However, *violence and control* domain (AUC = 0.66) *and sexual behaviour* domains (AUC = 0.37) were 'ineffective' (Hosmer *et al*., 2013) at discriminating between linked and unlinked crime pairs. This suggests that the target selection domain and crime scene characteristics domains were more effective at linking crime pairs. In other words, offenders displayed more distinct crime scene behaviours within these domains and were therefore easier to link. This does not suggest however, that violence and control behaviours and sexual behaviours should be disregarded, as the variability among these behavioural domains highlight the variability of offender's behaviour (Bateman & Salfati, 2007; Bennell *et al*., 2021; Schlesinger *et al*., 2010; Sorochinski & Salfati, 2010; Woodhams *et al*., 2019). In addition, these two behavioural domains are often more susceptible to external influence such as the interaction with the victim, whereas target selection and crime scene characteristics domains are considered more within the offender's planning and control. For example, the offender is able to select and target a specific victim however, they are not able to control how the victim might respond or react (Salfati, 2019). Therefore, these findings contribute towards the overall picture regarding the behaviour consistency and

distinctiveness of serial murder offenders, considering that the model demonstrated 'excellent' discrimination accuracy when all MO behaviours were included (AUC = 0.86).

It is important to reiterate that the purpose of the study was to examine whether behaviour consistency and distinctiveness exists, not to examine or generalise the frequency of specific variables or behaviours. More specifically, the descriptive results from the checklist of behaviours should not be generalised to all serial murder offenders in South Africa, as they are only representative of the sample used in the current study (Burrell *et al*., 2024). Additionally, if different murder series were included in the study, the outcomes regarding the frequency of crime scene behaviours (variables) could very well differ (Bennell *et al*., 2021; Woodhams *et al*., 2019). However, the researcher does highlight some of the frequency of findings of the variables which correspond with previous research studies examining crime scene behaviours of serial murder offenders, particularly in the South African context. Findings which had notable discrepancies are also presented, to demonstrate that the frequencies of the variables should not be generalised to the population of serial murder offenders both internationally as well as in South Africa.

Each behavioural domain will now be discussed further, highlighting some of the descriptive findings of the variables corresponding with findings from previous research. In addition, discrepancies will be addressed, as well as an examination the overall effectiveness of all data within each domain will be discussed, before comparing solved and unsolved outcomes for each domain. For ease of reading, percentages will be rounded to the nearest decimal.

5.3.2.1 Consistency and Distinctiveness of Target Selection Behaviours

With regard to target selection behaviours (such as the age, race, gender of victim, approach location etc.), Mann Whitney *U* tests determined that Jaccard's coefficient scores for all linked crime pairs were significantly larger than unlinked crime pairs, across solved and unsolved series. This suggests that offenders are consistent in target selection behaviours, as high levels of behaviour similarity are found across datasets. This finding mirrors previous research which found that serial murder offenders are consistent regarding the types of victims which they target (Bennell *et al*., 2021; Horning *et al*., 2015; Ressler *et al*., 1986; Salfati *et al*., 2015a; Sorochinski *et al*., 2015).

Overall, *target selection behaviours* displayed 'acceptable' levels (AUC = 0.75) of discrimination accuracy for all data (solved and unsolved) as well as all solved data (AUC = 0.78). Against expectation, excellent discrimination (AUC = 0.81) accuracy was found within the unsolved target selection domain. This indicates that the model was able to successfully distinguish between linked and unlinked crime pairs based on the Jaccard's coefficient probability values for target selection behaviours. This suggests that serial murder offenders not only display similarity (consistency) in their target selection behaviours across crimes, but that they are also distinct in relation to the target selection behaviours used in this research. As a result, target selection behaviours appear to be effective at linking crimes. Interestingly, the unsolved target selection domain displayed higher discrimination accuracy (AUC = 0.81) compared to the solved target selection domain (AUC = 0.78). However, there was a lower number of victims for unsolved murder series. This could suggest that there is more variability of an offender's behaviour regarding target selection behaviours as a series develops, which supports findings from previous research on serial murder offenders (Salfati, 2019). Alternatively, this could suggest a potential limitation of the sample, as only crimes which were forensically linked to a series were included in the research.

In other words, excluding cases which were not forensically linked could be considered a possible limitation of this study, as an offender could be responsible for more victims. For example, when examining unsolved case files, the researcher observed that the IPS had linked additional crimes to a (unsolved) series, based on behavioural evidence. However, the researcher could not include them in the current study as they did not meet the inclusion criteria of being forensically linked, which is necessary to establish the ground truth in crime linkage research (Burrell *et al*., 2024). As a result, unsolved cases which have not been forensically linked were outside of the data set (Zappalà *et al*., 2022). Therefore, serial offenders' victim count may not necessarily be lower or decreasing per se, but rather that they were not linked forensically for the purpose of this study. In addition, two of the solved series could be considered prolific offenders and elevated the mean victim count for solved series. Alternatively, it could be speculated that murder series which were solved had initially attracted greater scrutiny and urgency due to the high number of victims and offender prolificity (Chai *et al*., 2024), and therefore, were detected and apprehended sooner, or that the offender made more mistakes on which investigators capitalised. It would be

interesting for future research to examine the methods which investigators used to apprehend serial murder offenders, to determine the most effective strategies used to solve these series.

Although the study of the features of the variables and characteristics of the descriptive statistics is not the main purpose of the research, it is worth noting some of the comparable results found, as well as dissimilarities when compared to studies conducted both in South Africa and internationally. Most victims in the current study were Black (83%), followed by Coloured victims (9%), White victims (8%), and lastly Indian victims (less than 1%). Two Asian victims were found in Salfati *et al*. (2015b) while no Asian (0%) victims were in the current study. This highlights that frequencies of behaviours in the study should not be generalised to all serial offenders in South Africa, or to other countries, as different samples of murder series will have different outcomes. Although these findings differ regarding the race of victims in Australia, Canada, and the USA where most of the victims were reported to be White (James *et al*., 2018; McKinley & Petherick, 2021; Sorochinski & Salfati, 2010). These findings are comparable with findings from Salfati *et al*. (2015b), and are unsurprising within the South African context, as the majority of the population within South Africa is over 80% Black (Labuschagne, 2021). Racial demographics of victims often represent the natural demographics and composition of the country (Chopin & Beauregard, 2021a).

Results of the current study also found that just over half of the victims (52%) are classified as a vulnerable population group; including children (< 17 years old), and the elderly (> 65 years old). Vulnerable victims are individuals who can be overpowered easily, easily manipulated, and often have low social control (Egger, 2002; Horning *et al*., 2015; Salfati *et al*., 2015a). Female victims are also considered part of the vulnerable population group and almost 90% of the victims in the current study were female. This finding replicates previous research studies both internationally as well as in South Africa, which found that serial offenders target vulnerable victims, and predominantly females (Horning *et al*., 2015; Salfati & Sorochinski, 2019; Salfati, 2019; Salfati *et al*., 2015a; Sorochinski *et al*., 2015; Sorochinski & Salfati, 2010). In addition, the majority of victims in the current study were adult Black females and mirrored findings from Salfati *et al*. (2015b) study where middle-aged Black females were the predominant victims of serial murderers in South Africa.

The majority of offenders displayed consistency with regard to the selection of the gender of the victims which they targeted. Within the sample, 76% of offenders targeted only female

victims, 5% targeted only male victims, and 19% of offenders targeted both male and female victims. This is contrary to what Yaksic (2022) reported, as he stated that 48% of serial murder offenders in the USA kill both male and female victims. Interestingly, half of the offenders (2/4) who targeted both male and female victims (n = 4) in the study were from the only two prolific solved murder series, while half of the offenders (2/4) who targeted both genders were two unsolved murder series. Therefore, it could be suggested that as victim count increases, offenders target selection varies with regard to gender of victims, and that serial murder offenders who target both genders, are more difficult to link and, therefore, to solve. However, this is purely speculative at this stage, and future research should be conducted to determine whether this suggestion is plausible. This also highlights that the results of the frequency of the behaviours used in this study should not be generalised to the serial murder population in South Africa, as different outcomes may very well have been found if different murder series were included in the sample.

Victims were known to offenders in less than 8% of the solved series, with the majority of victims being strangers (92%) to the offenders. This finding further supports the notion that serial murder offenders in South Africa target victims who are strangers to them (73.3%) (Sorochinski *et al*., 2015). This is also consistent with international findings in Germany (Harbort & Mokros, 2001), Italy (Pakkanen *et al*., 2021), and Australia (McKinley & Petherick, 2021). In addition, the current study found that less than 5% of victims were sex workers, which is in line with previous studies examining serial murder offenders in South Africa (Horning *et al*., 2015). This appears to be considered somewhat unique to the South African context and is contrary to findings internationally such as in the USA, where sex workers are considered high frequency targets of serial murder offenders (Sorochinski & Salfati, 2019). Sex workers are considered vulnerable due to the nature of their work as they frequently encounter, and are willing to accompany strangers, often to an isolated and secluded location (Horning *et al*., 2015). The explanation provided by previous researchers posit that due to the high unemployment levels in South Africa, it is not uncommon for an individual to accompany a stranger with the promise of employment, which is ultimately a ploy to lure victims away to secluded locations in order to commit crimes against them (Hodgskiss, 2004; Labuschagne, 2021b; Labuschagne & Salfati, 2015).

Eighteen percent of victims survived the attempted murder/and or rape in the current study, which reiterates findings from Sorochinski and Salfati (2010) who found that 19% of victims

survived within the sample of victims of serial murder offenders conducted in the USA. Interestingly, 70% of offenders (7/10) from the unsolved series consistently murdered all their victim's, whereas only 54.55% of offenders (6/11) from the solved series consistently murdered all of their victims. This demonstrates that surviving victims are important to consider from an investigative standpoint, as surviving victims can often have vital information which may assist in solving a series, as indicated by the results of the current study. This also highlights the importance of including all victims within a murder series, regardless of survival status, as it further demonstrates behavioural variance and criminal diversification, as not all offenders are consistent in murdering victims (Hickey, 2016; Salfati *et al*., 2015a; Sorochinski & Salfati, 2010). While the majority of offenders murdered all (known) victims within a series (61.90%), three offenders (14.29%) murdered half of their victims (two solved series and one unsolved series). In these instances, it could be suggested that the high ratio of surviving victims suggests that murdering the victim was a precautionary act, and not the primary motive of the offender. This demonstrates what Freeman and Turvey (2012) refer to as criminal versatility, as offenders are multidimensional in their behaviours and motivations.

Victim count may also be relevant, as a high number of victims could result in a higher likelihood of more victims surviving (Salfati *et al*., 2015a; Sorochinski & Salfati, 2010). In some instances, victims were able to escape or survive the attack (Salfati *et al*., 2015a). Future studies should explore whether victims survived due to chance, or whether the offender purposely let a victim survive. It would be useful for future research to explore why some target victims were, or were not, murdered as the act of murder may be 'victim-specific' (Sorochinski & Salfati, 2010). Exploring whether there was a deeper psychological meaning for the offender, or whether it was purely situational (such as being interrupted by a passer-by, or the reaction of the victim, and/or inexperience of the offender), as well as ineffective killing methods or methods of control, would also add to the body of knowledge regarding serial murder offenders. The aspect of surviving victims could be helpful for investigators to consider when investigating unsolved cases (Salfati *et al*., 2015b; Salfati, 2019; Sorochinski & Salfati, 2010). It is recommended that cases where victims of rape and or attempted murder survived, be compared to unsolved murder cases, in order to determine possible linkages by examining similarities between target selection behaviours.

The results of the study suggest that offenders are generally consistent in target selection behaviours. This confirms previous research which has indicated that serial murderers often target similar types of victims across crimes, as the victim is often central to the fantasy of the offender (Hazelwood & Warren, 2003; Hickey, 2016; Labuschagne, 2012). This finding, which suggests that offenders are both consistent, and distinct enough from one another to be distinguished between crime series when examining target selection behaviours, is important for investigators as well as practitioners such as behavioural analysts. This functional behavioural domain is therefore likely to be beneficial for investigators to consider when linking and connecting crimes to a series, as serial murder offenders appear to select similar targets across crimes which is consistent with conclusions from Salfati *et al*. (2015a) study on serial murder offenders in South Africa.

However, variability in the data with regard to Jaccard's coefficient (as indicated by minimum and maximum values), suggest that not all offenders display behaviour consistency with regard to target selection behaviours, a finding consistent with previous research examining consistency of victims among serial murderers (Salfati *et al*., 2015a; Sorochinski & Salfati, 2010). Therefore, investigators need to take this into consideration during the course of their investigation, and not completely disregard cases where target selection behaviours may differ. For example, as mentioned by Freeman and Turvey (2012), offending motivation and behaviour may differ as a result of the offender's mood, substance use and/or situational circumstances or motivation/s at that particular time (Bougard & Hesselink, 2021). As a result, investigators may need to take into consideration other aspects of the crime scene to link cases, such as geographical locations and spatial proximity, which have proven to be useful at linking crimes (Snook *et al*., 2005b; Tonkin *et al*., 2011).

However, overall, this behavioural domain appears to be useful and effective at linking crimes, particularly since behaviours within this domain are considered more within the control of the offender. Offenders can select and determine who, and when, they choose to attack and the conditions under which they choose to do so. Therefore, it is suggested that behaviours considered within the offender's control are considered more consistent as they are less susceptible to external or situational influence in comparison to, for example, sexual behaviours (Bennell *et al*., 2021; Ewanation *et al*., 2023; Woodhams *et al*., 2007). In addition, it could be speculated that target selection behaviours are related to pre-offence planning behaviours (Reale *et al*., 2021, 2022). This is consistent with findings from

Sorochinski *et al*. (2015) who found that serial murder offenders in South Africa use pre- and post-planning offence strategies before they commit their crimes.

5.3.2.2 Consistency and Distinctiveness of Sexual Behaviours

Sexual behaviours were variables such as state of victims' dress/undress, exposing of victims' body parts, penetration of genital-anus, injuries to victims' genitals, seminal fluid found at the crime scene etc. Results from the Mann Whitney *U* test indicate that Jaccard coefficients for all sexual behaviours (solved and unsolved) linked crime pairs was significantly larger ($p < .001$) than all unlinked sexual behaviour crime pairs. Despite sexual behaviours displaying significant differences between linked and unlinked crime pairs across datasets, the effect sizes were small within this behavioural domain. This suggests that lower levels of behavioural similarity were present among offenders in this sample with regard to sexual behaviours, and, therefore, there was less behaviour consistency.

As indicated by Jaccard's coefficient minimum and maximum values, there was perfect similarity (1), as well as perfect dissimilarity (0) amongst linked and unlinked crime pairs within the sexual behaviour domain. Variability within this domain was also apparent when examining the Boxplots, as shown in **Figure 4.4** of the previous results chapter. Therefore, some offenders appear to be very consistent while some offenders are very inconsistent which confirms findings from previous research studies regarding the complexity of serial sexual behaviour (Bennell *et al*., 2021). The low effect size between the two linked status' further supports the notion that sexual behaviours are not as effective at linking crimes, based on the findings of the behaviours of series used in this study. This finding is supported by previous research regarding the sexual component of serial murder offenders who found that the sexual component to be the least consistent (Bateman & Salfati, 2007). This could be as a result of a lack of apparent or observed sexual activity which is often not available (Bateman & Salfati, 2007; Salfati, 2019; Zappalà *et al*., 2022).

Additionally, sexual behaviours were ineffective at linking crime pairs as demonstrated by the AUCs amongst datasets within this domain. Unsolved cases' sexual behaviours had low levels of discrimination accuracy (AUC = 0.58). While all sexual behaviours (solved and unsolved) (AUC = 0.37) and solved sexual domain (AUC = 0.34) indicate that the model's performed worse than chance. This supports research findings by Bateman and Salfati (2007)

who found that the sexual component was the least useful at connecting serial murder offenders in their study. It also further demonstrates findings of research conducted by Bennell *et al*. (2021) who highlighted the complexity of behavioural patterns underlying serial sexual assaults. It was reported that victim-offender interaction can produce varied behaviours exhibited at crime scenes, and a greater range of behaviours can be displayed (Bennell *et al*., 2021). The model's inability to classify and discriminate between linked and unlinked crime pairs, as indicated by the ROC analysis, suggests that the model had insufficient data, and was unable to learn patterns related to crime pairs (Bennell *et al*., 2021) This could suggest that the quality of data available could be a limitation in the study (Bennell *et al*., 2015a). In other words, the variables within these domains may not been operationalised in such a way that it is able to capture the behavioural domain effectively (Bennell *et al*., 2021).

Firstly, taking theoretical assumptions into account, not all serial murder offenders are sexually motivated (Salfati *et al*., 2015b). Therefore, in some series there was little to no data pertaining to sexual behaviours. This means that less information was available to the researcher regarding sexual behaviours, which could have resulted in an underestimation of the domain's discrimination ability. For example, 14% (3/21) of the offenders were consistent in leaving victims fully dressed and had no other evidence to suggest or indicate any sexual behaviours. Secondly, some of the information pertaining to sexual acts is often not known, as observable evidence of sexual activity is often not available (Bateman & Salfati, 2007; Salfati, 2019; Zappalà *et al*., 2022). For example, presence or absence of DNA at the crime scene may vary across crimes, or may not be available at all, due to circumstances related to each case (Sorochinski *et al*., 2015). For instance, degradation of forensic evidence at a crime scene due to delay in body recovery, body decomposition, poor crime scene investigation, or forensic awareness of an offender (such as an offender using a condom), limit crucial evidence relating to sexual behaviours (Sorochinski *et al*., 2015). For example, whether the victim was raped or whether saliva and/or seminal fluid was present on the victims or at the crime scene (Charan, 2023; Minkler *et al*., 2024).

Lack of observed sexual evidence is viewed as a limitation, and an issue which investigators face during their investigations, highlighting the need for alternative strategies to connect crimes when forensic evidence is lacking or unavailable (Rossouw & Palys, 2025; Woodhams & Labuschagne, 2012a). However, these results are not indicative that sexual

behaviours or acts did not occur as the absence of evidence of rape or sexual assault does not mean that rape or sexual assault did not occur (Machisa *et al*., 2017). In addition, it could suggest that the offender was forensically aware and/or took precautionary actions such as using a condom or removing evidence of seminal fluid (McKinley & Petherick, 2021). This is consistent with international studies which found that serial offenders have greater forensic awareness in comparison to once off murderers (Chan *et al*., 2015; McKinley & Petherick, 2021). Notably, almost 90% of serial murder offenders in South Africa had a prior criminal history (Horning *et al*., 2015). Therefore, because of prior contact with law enforcement, they may consequently use detection and avoidance strategies during their crimes, such as destroying or removing forensic evidence (Chopin & Beauregard, 2021b; Reale *et al*., 2020).

Furthermore, sexual gratification may have also been obtained through the fantasy of the offender and achieved through other types of behaviours such as verbal script or actions (Salfati, 2019; Woodhams & Labuschagne, 2012a). A further limitation is that lack of physical evidence such as genital injuries, does not necessarily indicate that rape or sexual assault did not occur. Many victims do not necessarily show genital injuries, particularly (adult) women who have engaged in consensual sexual intercourse before (Orellana-Campos, 2020; Walker, 2015). Additionally, few rape victims in South Africa reportedly displayed physical injuries or evidence of rape, and only 56% of rape victims in South Africa had evidence of genital-anal injuries (Machisa *et al*., 2017). Offender's may control the victim through verbal threats or threats of harm, with a weapon present at the scene (Turvey & Freeman, 2012b). As a result, victims, out of survival and fear, may believe that if the offender is satisfied sexually, they will survive and, as a result, may not physically resist the sexual assault. Therefore, the rape may not have been particularly forceful or violent (but still non-consensual), which could explain why there are no visible genital injuries (Machisa *et al*., 2017; Orellana-Campos, 2020; Walker, 2015).

The majority of victims were found in various states of undress, and only 22% of victims were fully clothed. Although Salfati *et al*. (2015b) posited that serial murder is not an inherently sexual crime, the state of undress of victims does provide support for the notion that serial murder offenders in South Africa are often sexually motivated, as there is a sexual nature or element to their crime (Labuschagne, 2021). This is interesting to consider as, despite the majority of crime scenes displaying a sexual element in the way in which the

victim is found undressed, few victims had evidence of vaginal penetration (35%), and seminal fluid was only present in 32% of these cases. No seminal fluid was identified in the victims who had evidence of anal penetration (6%). Seminal fluid was only located at 11% of the crime scenes, with just over 2% found on the victim's body or victims clothing. A condom was found at fewer than 3% of the crime scenes. This could also be explained due to the natural environment in which victims of South African serial offenders are found, such as high temperatures and animal's scavenging on decomposing bodies, which may degrade physical evidence such as DNA or seminal fluid (Sorochinski *et al*., 2015).

Fewer than 2% of crime scenes had evidence of digital penetration, and these instances were reported to the police from the same offender from one of the solved series. Genital mutilation occurred in fewer than 5% of cases, with one series where the genitals were consistently removed from all the victims in the series. This series was notably the sole instance in the study which consisted exclusively of male victims. When examining the raw data, few cases had evidence of foreign object insertion. Therefore, there may be exceptions, and these instances could be instances related to the signature of an offender (Hazelwood & Warren, 2003; Van der Watt *et al*., 2014). However, as this research is examining overall behaviour and consistency and distinctiveness across all MO crime scene behaviours, as well as across functional behavioural domains, unique and distinct crime scene behaviours should not be dismissed or excluded by investigators as linking factors. For example, a unique sexual behaviour of inserting a foreign object inside a victim's vagina should not be ignored however, investigators may need to be cognisant that this does not necessarily mean that the offender will consistency use this type of behaviour with every victim, and for various reasons. Therefore, this research indicates that, overall, sexual behaviours are unlikely to be useful for linking murder series.

In addition, the psychological motive and meaning behind an offender's behaviour is not known. Therefore, the researcher's inferred meaning of certain behaviours could have resulted in limitations of the domains effectiveness at linking crimes (Bennell *et al*., 2021). For example, some offenders, to control the victim, may instruct victims to undress as a way to induce shame and a sense of vulnerability (Freeman & Turvey, 2012). Therefore, the variables used to code sexual behaviours may not accurately reflect the usefulness of this functional behavioural domain, as some of the variables used to code these features may not comprehensively reflect and capture sexual behaviours. For instance, there are many

behaviours which are coded as absent or missing, particularly in the sexual domain, and it is suggested that this domain can often be influenced by interaction with the victim and therefore situational and contextual factors (Bennell *et al*., 2021; Bennell & Canter, 2002). Although this could be viewed as a limitation of the study, it does provide an insight into the complexity of examining serial murder offenders' behaviours, and the challenges researchers and investigators face when inferring behaviour of offenders into perceived functional domains (Bennell *et al*., 2021).

However, it can be argued that there are limited ways of capturing evidence of sexual behaviours with deceased victims (Bennell *et al*., 2021). Without any forensic evidence, this will continue to be a limitation to investigations and researchers examining crimes of murder, as the victim is not alive to provide details on what did, or did not, occur. Despite the above limitations, this finding does provide further insight and an interesting point for speculation and reflection. Studies on serial sexual offenders indicate that offenders are consistent and unique in their crime scene behaviours (Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a; Woodhams & Toye, 2007). For example, findings from Woodhams and Labuschagne (2012a) indicate that serial sexual offenders were consistent in their overall MO behaviours, as suggested by Jaccard's similarity coefficient scores between linked and unlinked crime pairs with resulting AUC of .88. However, the variables used in their study were often descriptions of what the victim relayed to investigators such as: what the offender had done; what was said between the offender and victim; and what sexual acts had occurred. In other words, with living victims of sexual crimes, the interaction between the victim and offender was able to be documented and recorded (Woodhams & Labuschagne, 2012a), whereas the current research was limited with that type of information due to victim's being deceased.

In murder cases, information related to victim-offender interaction is absent due to the victim being deceased, therefore evidence and important information related to sexual behaviours is lost. Findings in Horning *et al*. (2015) found that serial offenders were consistent in their use of the *victim as vehicle*, suggesting that the interaction with the offender was common among South African serial murder offenders. This means that an offender's involvement and interaction with the victim influences and impacts on the level of consistency of an offender (Bateman & Salfati, 2007). Victims used as vehicles to the offender, suggest that the victim plays an active role in the fantasy of the crime, and are reported to be less

consistent as series progressed due to loss of control of the offender (Horning *et al*., 2015). Points for future research to explore could include whether the fantasy is more important, or, rather, the act of being violent and aggressive and committing physical acts. In other words, could the interaction with the victim (and the psychological meaning the offender attributes to this interaction) be more important to the offender than purely acting out a behaviour? Additionally, does the offender have specific scripts as found in previous sexual assault and serial rape research (Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a) which are more consistent in determining the outcome of a behaviour?

Victims who survived may have survived or been released for various reasons, which were 'victim specific' (Sorochinski & Salfati, 2010). Therefore, the fact that they survived could indicate that this situation was different or unique (for unknown and a multiple of possible reasons), and, therefore, the behaviours or acts may not be consistent with what other (deceased) victims were subjected to. However, in the absence of a surviving victim or witness, the only other way information pertaining to sexual behaviours and victim offender interaction could possibly become available would be through reports from the offender him/herself. In addition, obtaining information from offenders may not be accurate as they may falsify information, whether it be for self-entertainment and sensationalism, fear of suffering further consequences or punishment if they do disclose non-consenting sexual acts, or for other, unknown reasons. Therefore, the reliability of information gathered from an offender disclosing such information, could be questionable and unreliable (Bennell *et al*., 2021; Canter, 2000).

Some of the data were so old that many investigators have left SAPS or retired and could not be engaged further on some of the cases. Therefore, coding accuracy should ensure that crime scene behaviours are captured accurately and with precision, as the more accurate and exact the coding is, the more accurate and exact the performance metrics (Davies *et al*., 2019; Keatley & Clarke, 2020). This finding is still important as sexual behaviours contribute towards the overall consistency and distinctiveness of offenders at crime scenes, despite being ineffective at an individual functional behavioural domain level. Therefore, this behavioural domain should not be disregarded but could be a focus for further research studies, to explore how to best capture and operationalise sexual behaviours more effectively.

5.3.2.3 Consistency and Distinctiveness of Violence and Control Behaviours

Median Jaccard coefficient of all linked crime pairs for violence and control behaviours (such as COD, non-lethal injuries, methods used to control the victim such as restraints etc.) were significantly larger than unlinked crime pairs, as indicated by Mann Whitney *U* test results. Results were consistent across datasets within this domain, and each had a corresponding small effect size. The small effect size across datasets within this domain suggests that offenders display lower levels of consistency amongst violence and control behaviours. Lower levels of consistency, as measured by Jaccard's coefficients within the violence and control behavioural datasets, indicate variability in offender's behaviour. This provides support for the learning and experimenting hypothesis where offenders are more likely to alter their behaviour during or after committing the offence (Canter, 2004; Canter & Youngs, 2008). Sorochinski and Salfati (2010) suggest that variability of serial murder offender's behaviour could be due to the offender losing control. This loss of control could lead to increased frustration as the offender's satisfaction or fantasy is not fulfilled and, therefore, they adjust their behaviour to achieve their goals (Sorochinski & Salfati, 2010). Regarding discrimination accuracy, low levels of linking accuracy were demonstrated across datasets among violence and control behaviours. Low levels of discrimination accuracy were demonstrated by all violence and control behaviours (AUC = 0.66), and solved violence and control behaviours (AUC = 0.61). Unsolved violence and control behavioural domain performed no better than chance (AUC = 0.50). Based on these findings, this suggests that violence and control behaviours were ineffective for linking purposes.

In murder cases, information is lost due to the victim being deceased. For example, an offender may have presented and displayed a firearm or knife as a method to control the victim, but they did not use it to wound the victim. In addition, verbal threats may have been used by the offender to intimidate victims and as a method to control the victim (Woodhams & Labuschagne, 2012a). Some of the information recovered from the different series resulted from information obtained from a surviving victim, for example, providing information that the offender approached them by car, or the offender had a knife or firearm as a way of forcing them to do what the offender instructed (Horning *et al*., 2015).

Results of the current study indicate that just over 70% of offenders (15/21) were inconsistent in the manner of death caused to victims, with only six series (28.57%) displaying complete consistency in COD. This corresponds with previous research conducted on serial murder in South Africa, which found that it is common for serial murder offenders to have multiple methods of murdering victims (Labuschagne & Salfati, 2015). In addition, patterns of violence were also found to be the least consistent of serial offender's behaviours (Salfati *et al*., 2015a). Considering previous research findings, there are several suggestions why this finding is relatively unsurprising. Salfati *et al*. (2015a) found that the variability of offending behaviours was influenced by the level of interaction with the victim. For example, a victim who does not resist might experience less violence and control, whereas another victim who fights back could experience more violence and aggression, and more measures of control are needed (Salfati *et al*., 2015a). As a result, there may be victim-specific behaviours which may display consistency, and this could be an avenue for future research (Sorochinski & Salfati, 2010). In addition, sadistic offenders who enjoy inflicting pain on others, could engage in certain behaviours as they serve the fantasy of the offender (Gee & Belofastov, 2015). Conversely, an offender who is not able to fulfil their fantasy may engage in more violence and control due to increased frustration (Hickey, 2006). Additionally, research suggests that serial murder offenders intentionally alter crime scene behaviours, particularly the method used to murder the victim (Chai *et al*., 2021).

A majority of the victims in the current study were murdered by strangulation (28.57%), sharp objects (15.87%), followed closely by blunt force trauma (15.08%). Whereas, in the sample studied by Salfati *et al*. (2015b), the majority of victims were killed by gunshots (30.2%), followed by blunt force (27.6%), strangulation (25.7%), and stabbed by a sharp object (10.8%). This highlights the fact that variables of the studies should not be generalised to the population of serial murder offenders, as different samples (cases) used will result in different frequencies of variables. In addition, the researcher could have incorrectly considered that the act of restraining the victim's hands was an act of control, whereas it could have been related to a sexual theme and the acting out of an offender's fantasy. This also highlights the principle of motivational and behavioural variance, where one behaviour can serve or act as multiple functions for an offender (Freeman & Turvey, 2012).

This further highlights the complexity of offending behaviour, and the limitation in interpreting or inferring the intention of crime scene behaviours and the motivations behind

them (Beauregard & Bouchard, 2010; Bennell *et al*., 2021). In addition, Freeman and Turvey (2012) warn against the inductive profiling of offenders, where the investigator or criminal profiler (or researcher in this instance) infers behavioural meanings based on crime scene behaviours, as this should and could only be interpreted in the context of the individual crime scene with that specific offender. Therefore, future research studies should explore whether alternative methods are able to operationalise these variables more effectively, before absolute or certain conclusions can be made. Exploring the reasons behind potential changes in offending behaviour, is an important avenue for future research.

In a previous research study conducted on South African serial murder offenders (n = 36 solved series, Salfati *et al*., 2015b) gunshots were the leading COD (30.2%) of victims, while no instances of gunshots as COD were found in the current study. The reason for the high percentage of victim's COD as a result of gunshots in Salfati *et al*. (2015b) study is that when a firearm was used to murder victims, there was a high victim count within those series, and only 8.3% of the offenders (3/36) used firearms (gunshots) as the COD (Labuschagne, 2021). Therefore, the finding of the current study does provide further support that South African serial murderers do not often use firearms to murder their victims. However, the absence of visible injuries on a victim does not suggest that a particular weapon was not present at the scene. For example, although none of the victims had any gunshot injuries in the current study, this does not indicate that a firearm was not present at the scene. This type of evidence would only be known and available through testimony of a surviving victim or a witness who reports it to law enforcement, which occurred in two of the cases in the current study. Therefore, the lack of evidence of a firearm present at crime scenes could suggest that the offender planned the attacks in advance and planned to use the firearm in order to control the victim. This is consistent with Salfati *et al*. (2015a) finding that South African serial murder offenders pre-plan their offences. Other possible reasons for an offender not using the firearm could be that the offender may have forensic awareness of ballistic evidence, which could link them to a crime, or simply that the sound of the firearm could attract unwanted attention, compromising the crime scene for the offender (Labuschagne, 2021).

This also highlights the potential cultural and contextual nature of the variables in South Africa. For example, the offender may be carrying a firearm due to the high crime rate in South Africa (where the firearm would be an effective source of self-defence and protection) as well as easy access to illegal firearms (Hodgskiss, 2004; Horning *et al*., 2015). However,

the offender may also have been carrying a firearm as they had pre-planned the crime, and the firearm was instrumental in controlling the victim (Salfati *et al*, 2015a). This hypothesis is consistent with findings from previous research done by Salfati *et al*. (2015a) which indicated that South African serial murder offenders engage in post-offence planning at the pre-offence planning stage. In other words, South African serial murder offenders often only have two crime scenes, the approach location and body disposal location. This is likely because most serial murder offenders in South Africa do not have a vehicle to transport a deceased body, so victims are lured to the (often pre-planned) disposal site, while they are still alive (Labuschagne, 2021). This is contrary to serial murder offenders in the USA who generally have three crime scene locations; approach location, crime scene location, and body recovery location, as they have access to a vehicle to transport the body of the deceased victim (Labuschagne & Salfati, 2015; Salfati *et al*., 2015a; Sorochinski *et al*., 2015).

Due to the low economic status of serial murder offenders in South Africa, they are often on foot as they do not own vehicles (Hodgskiss, 2004; Salfati *et al*., 2015a). As a result, they choose to lure victims away to secluded locations with a con story (Horning *et al*., 2015; Salfati *et al*., 2015a). It is thus possible that the offender may have a firearm present at the crime scene to control the victim but chooses not to discharge the firearm or use it as a method to murder the victim, as it could compromise the offender's ability to escape the crime scene undetected. Put differently, if the offender had to shoot the victim, this could result in unwanted attention through the loud sound, and therefore, the offender would not be able to plan in advance or control who may hear the gunshot (Labuschagne & Salfati, 2015).

The behavioural checklist used to capture the violence and control behavioural domain could have been limited at effectively capturing violence and control behaviours. For example, injuries could have been extrapolated further to indicate where exactly the injuries occurred, i.e. head, legs, arms etc. Conversely, wounding patterns may have proven to be more effective at linking crimes if they were categorised into process oriented versus goal orientated behaviours. However, this would require subjective interpretation of the coder, which could possibility result in coding bias (Davies & Woodhams, 2019). Therefore, future research could explore whether discrimination accuracy is more effective if behaviours are subdivided into wounding themes or types, and the influence of coding bias by doing so. As a result, this behavioural domain should not be seen as ineffective, and further research

studies should adjust and explore ways to best capture these types of behaviours more effectively. These findings are further interesting since overall, they contribute towards a picture of the offender and their consistency and distinctiveness in their crimes of serial murder in South Africa, despite being ineffective at an individual behavioural domain level. Interaction with the victim is important, particularly regarding process-oriented wounding strategies as the offender may also derive satisfaction through manual killing of the victim (Salfati & Bateman, 2005).

5.3.2.4 Consistency and Distinctiveness of Crime Scene Characteristics

Crime scene characteristics were variables such as the body disposal site, the surrounding features of the crime scene, the position of the victim's body, weapons left at the scene, and whether residential or in the open veld etc. As indicated by the statistical analysis (Mann Whitney *U* test), all linked crime pairs for crime scene characteristics variables were significantly larger ($p<.001$) than unlinked crime pairs across datasets within this domain. However, results of the effect sizes demonstrate that offenders within the solved series displayed higher levels of behavioural consistency than offenders within the unsolved series. This finding could suggest that solved murder series appear more consistent which may indicate that they were easier for investigators to identify and link crimes to a series. Regarding discrimination accuracy, crime scene characteristics domain displayed varying results. While all data (solved and unsolved series combined) demonstrated 'acceptable' levels of discrimination accuracy (AUC = 0.78), 'excellent' discrimination accuracy was demonstrated for all solved crime scene characteristics (AUC = 0.83). However, the model was ineffective at discriminating between linked and unlinked crime pairs for unsolved crime scene characteristics (AUC = 0.66). In other words, while levels of similarity of crime pairs were demonstrated across crimes, indicating behaviour consistency, they were not distinct or unique enough to be able to discriminate from other crime pairs.

An interesting finding was that unsolved crime scene characteristics domain was ineffective at linking crime pairs whereas solved crime scene characteristics displayed excellent linking ability. This is a curious finding as the crime scene characteristics functional behavioural domain is essentially: "what does the investigator see and find when they arrive at the crime scene?". This could provide support for the hypothesis that unsolved series are less distinguishable and could result in a delay in identifying a crime scene as being linked to

another. Therefore, one could argue that, because the crime scene actions were not noticeably similar or unique, they are unsolved. However, the researcher argues that the issue is more complex, and whether a case is solved or not is determined by many factors such as police resources, availability of forensic evidence, as well as 'luck' or chance as suggested by Yaksic *et al*. (2021). In addition, it could be argued that the fact that they are linked forensically, demonstrates that they have in fact been linked. Consequently, linked status does not determine whether a series is more likely to be solved or not. Furthermore, once-off victim murder cases are not linked to another crime, however, are still solvable (Chan *et al*., 2015; Pakkanen *et al*., 2015b). Therefore, despite a case being linked to another offence, this does not necessarily make it easier for investigators to link the crimes to a particular offender and solve the crime. Hence, it is highly recommended that future research explores the most common and effective investigative strategies which were used to solve murder series and/or once-off murder cases.

No victims (0%) were discovered in cars compared to Salfati *et al*. (2015b) study (4.3%), and there was a higher percentage of victims' bodies found within their residences and/or buildings in the current study (40.78%) compared to 22% of victims in the study of Sorochinski *et al*. (2015). However, as found in previous research on South African serial murders, more than half of the victims were discovered outside in the current study (51.59%) such as the open veld (Horning *et al*., 2015). This is considered relatively unique to the South African context in comparison to the USA. It could be attributed to high compact living conditions, particularly where vulnerable, unemployed victims may be located (Hodgskiss, 2004; Horning *et al*., 2015). This corresponds with the general MO of offenders in South Africa of approaching stranger victims with the offer of employment, luring them to secluded, isolated outside areas where they murder them (Horning *et al*., 2015). In addition, due to the high crime rates in South Africa, there are often additional security measures (such as security cameras) in residential areas (Hodgskiss, 2004). This provides support for the findings form Salfati *et al*. (2015a) which indicated that South African serial murder offenders engage in post-offence planning during the pre-planning phase of the offences.

In the majority of cases, victims were found on their backs (32.54%) and were not covered or concealed in any way (76.98%). South African serial murder offenders reportedly do not attempt to conceal crime scenes in comparison to their USA counterparts, due to the pre-offence planning by South African serial murder offenders who predominantly commit

crimes in isolated outdoor environments (Horning *et al*., 2015; Salfati *et al*., 2015a). As mentioned previously, serial murder offenders in South Africa are less likely to own or have access to a vehicle in order to relocate the victim's deceased body to a secluded place for disposal. As a result, the victim is lured and walked to a (often preselected) secluded location where the crime is committed, and the body is left and disposed of (Salfati *et al*., 2015a). As a result, due to high temperatures in South Africa which speeds up decomposition, and a delay in recovering the body, evidence is often lost and/or destroyed due to temperatures, time lapsed, and animal activity (Horning *et al*., 2015; Salfati *et al*., 2015a).

None of the victims in the unsolved series were found dismembered. However, half of the victims who were dismembered in the solved series (n = 4) had their genitals removed and taken, all of which were exclusively male victims from the same series. Of weapons found at the scene, the majority of offenders appeared to have either brought weapons to the scene or removed weapons from the crime scene as 75.40% of cases there was no weapon found. This is consistent with Sorochinski *et al*. (2015) in which 76.1% of offenders brought weapons to the crime scenes. This further corroborates Sorochinski *et al*. (2015) findings that South African serial murder offenders display more pre-planning in their crimes, as most offenders brought weapons to the crime scene. The results of the current study also provide support for this hypothesis and could also suggest pre-planning and forensic awareness on the part of serial offenders (Beauregard & Bouchard, 2010; Eichinger & Darjee, 2021; Salfati *et al*., 2015a). Notably, 89.3% of serial murder offenders in South Africa had a prior criminal history (Horning *et al*., 2015). By removing weapons from the crime scene, offenders are able to mitigate leaving forensic evidence behind, such as DNA or fingerprints (Beauregard *et al*., 2022; Chopin *et al*., 2020; Pakkanen *et al*., 2015b; Reale at el., 2021; Yaksic *et al*., 2021). In addition, the offender may find the weapon brings a sense of comfort as they have been able to successfully murder a victim with the weapon thereby continuing to use it in future offences as this is a MO which has *worked* for the offender (Hazelwood & Warren, 2003; Van der Watt *et al*., 2014). Interestingly, a higher percentage of offenders from the unsolved series left ligatures on victims at the crime scene (19.15%) than offenders from the solved series (12.66%). Future research should explore whether there is any significance to this finding.

Unsolved series used in the current sample do not necessary indicate that a case is "cold" and unsolvable per se. For example, in half of the unsolved series (n = 5), the last victim was

murdered within the last five years before data collection concluded in 2023. These five years were also significant as a result of the COVID-19 pandemic, failing infrastructure related to power, and lack of resources such as backlogs at forensic laboratories with regard to DNA results which could have impacted on police investigations (Machisa *et al*., 2023). Interestingly, Yaksic (2022) reports that only 22% of serial murder offenders are caught within the first five years. Therefore, taking the above into account, it is quite probable that the unsolved cases included in the study could be 'solved', within a matter of time, and not necessarily that they were not identified as being linked as part of a murder series. This is important for crime linkage research, as previous studies have suggested that solved series were solved because they were easier to link (Woodhams & Labuschagne, 2012a).

This reiterates the importance of using both forensic and linkage techniques, as they can complement one another (Bennell & Woodhams, 2015; Labuschagne, 2012, 2015). ROC analysis can provide direction and inform practitioners and investigators when to consider linking a crime to a series. It has also been suggested that there has been an increase in forensic awareness amongst serial murder offenders (Beauregard & Bouchard, 2010; Chopin *et al*., 2020), Alternatively, some offenders may become more cautious, or change their behaviour patterns after committing a crime, to avoid detection, and to deter investigators from connecting a crime to a series (Salfati & Bateman, 2005; Yaksic, 2023).

Additionally, the variables used in this study reflect the 'how' and 'what' an offender did during the commission of their crimes. In other words, the variables reflect the MO of serial murder offenders. The functional behavioural domains, although pragmatic and atheoretical (Bennell *et al*., 2021), do not reflect 'why' or the intent the offender chose to do or not do certain behaviours which would pertain to the motive/s and signature of the offender. The signature of the offender is satisfied through fulfilling the fantasy and psychological desire of the offender (Van der Watt *et al*., 2014). However, the psychological reasoning, motivation and fantasy of the offender is beyond the scope of this research study and could provide focus for future research (Crabbé *et al*., 2008).

The findings of the study suggest that behaviours which are based predominantly on the interaction with the victim, and, therefore, less in control of the offender, are less helpful at linking crimes. Whereas behavioural domains such as target selection and crime scene characteristics appear to be more useful and effective at linking crimes. However, even

within these domains there is still variability within the data which indicates that not all offenders display consistency, which corresponds with findings from previous crime linkage research (Bennell *et al*., 2021; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). Motivational and behavioural variance can be influenced by factors such as the interaction with the victim, substance use, the offender's mood, unexpected witnesses, or unintended consequences or outcomes, causing the offender to alter and change behaviours accordingly (Sorochinski & Salfati, 2010; Turvey, 2012a). Future research should explore whether existing variables can be developed further or transformed, to improve the model's performance within functional behavioural domains. Based on the above findings and limitations, the researcher determined that examining all behaviours was more effective at determining offenders' behaviour similarity and distinctiveness, rather than functional behavioural domains. As a result, the researcher chose to apply various decision thresholds (following recommendations by Ewanation *et al*., 2023) to determine performance metrics such as error rates to all data.

5.4 IMPLICATIONS AND USEFULLNESS OF THE STUDY

5.4.1 Theoretical Implications

Previous research studies have found support for the underlying principles of crime linkage, namely that offenders behave in consistent yet unique ways (Bennell & Canter, 2002; Davidson & Petherick, 2021; Tonkin *et al*., 2012a; Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). As a result, offenders can be distinguished from other offenders based on crime scene behaviours, thereby linking crimes (Bennell & Canter, 2002; Pakkanen *et al*., 2021; Tonkin *et al*., 2017; Woodhams *et al*., 2019). The underlying principles are important for empirical research in order to assist and inform police decision-making at different stages of the investigative phase as well as during the trial phase (Davies *et al*., 2019; Labuschagne, 2015a; Woodhams & Davies, 2021). While there has been a significant interest and research on serial murder over the decades (Yaksic, 2024) few studies have tested the underlying principles of crime linkage research on this crime type (Pakkanen *et al*., 2021). Therefore, this study contributes to a surprisingly understudied topic in relation to testing the principles of crime linkage.

In addition, no study to date has included unsolved series when examining serial murder behaviour consistency and distinctiveness (Melnyk *et al*., 2011; Pakkanen *et al*., 2021).

Therefore, this study provides support for the assumptions underlying crime linkage, using an ecologically valid sample of South African serial murder offenders. Using quantitative measures, this study found that linked crime pairs were significantly more similar in behaviour than unlinked crime pairs, when examining Jaccard coefficients similarity scores between crime pairs. This provides support for the behaviour similarity and, therefore, consistency of serial murder offenders. The logistic regression model was able to discriminate between linked and unlinked crime pairs effectively, after data was cross-validated using the LOOCV method as done in previous crime linkage research (Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). As a result, providing additional validity of crime linkage using ROC analysis.

Functional behavioural domains considered to be within the offender's control, and less likely to be impacted by situational contexts such as the interaction with the victim, appear to be more effective at distinguishing between linked and unlinked crime pairs (Bennell *et al*., 2021; Tonkin *et al*., 2012a). In addition, these functional behavioural domains could also suggest pre- and post-offence planning behaviours of offenders (Reale *et al*., 2021; Sorochinski *et al*., 2015; Tonkin, 2015). Overall, however, examining an offender's overall MO, by including all crime scene behaviours, is more effective at linking crime pairs with regard to consistent and distinctive behaviours, despite situational or contextual influences (Bennell *et al*., 2021; Burrell *et al*., 2024; Tonkin, 2015).

5.4.2 Practical Implications

Crime linkage is useful to inform law enforcement and investigative decision making (Davies *et al*., 2019; Woodhams *et al*., 2019). From a practical perspective, results of the study suggest that all MO crime scene behaviours should be considered when examining overall behaviour consistency and distinctiveness, rather than examining separate functional behaviour domains. This is because higher levels of discrimination accuracy were found when all behaviours were considered. There are predominantly two contexts which behavioural evidence such as crime linkage is beneficial to; the investigative phase, and the trial phase such as legal proceedings (Burrell *et al*., 2024; Davies *et al*., 2019; Davies & Woodhams, 2019; Ewanation *et al*., 2023; Labuschagne, 2015a).

As recommended by Ewanation *et al*. (2023), the researcher provided full ROC curves to combine datasets which were effective at linking crime pairs. These results indicate that combining all behaviours is more effective at linking crimes, than functional behavioural individual domains (as seen in **Table 4.7 and Table 4.8**). The researcher further examined the performance metrics and error rates between solved and unsolved datasets, to determine how the datasets differed and the possible implications for law enforcement. Providing full ROC curves, enables a visual representation at which point to plot a threshold. As demonstrated by **Figure 4.8** in the previous (results) chapter, a combination of all MO behaviours still outperformed target selection and crime scene characteristics behavioural domains, across all decision thresholds. As a result, the researcher chose to apply different thresholds to determine performance metrics and outcomes on datasets including all MO behaviours, rather than individual functional behavioural domains, due to the effectiveness of using all behaviours (Ewanation *et al*., 2023).

Youden's index was calculated to determine at which point the number of hits were maximised while the number of false positives were minimised. Although most research refers to Youden's index as the 'ideal' cut off point, Ewanation *et al*. (2023) caution against this. They argue that various thresholds should be explored, to determine the effect which each threshold has on the hit rate and false alarm rate, at different phases of the investigation and legal proceedings, which have yet to be done or presented before in crime linkage research (Ewanation *et al*., 2023). Consequently, the researcher applied a lenient, mid-range, strict, and very strict threshold to the data which will now be explored further in terms of the practical implications for investigative and legal settings.

5.4.2.1 Investigative Phase

The researcher selected thresholds to align with previous research studies involving crime linkage (Davidson & Petherick, 2021; Woodhams *et al*., 2019), and as suggested by Ewanation *et al*. (2023). Implementing and utilising different thresholds may be helpful for investigative purposes such as when to form a task force or task team (Turvey & Freeman, 2012a). When a lenient threshold was applied, a hit rate of 90% was selected, suggesting behavioural commonality. This would suggest that there is a likelihood that the offender could be linked to the crime however, there is a high possibility that they are incorrectly linked due to the high false alarm rate (Ewanation *et al*., 2023). Therefore, cases should be

examined to determine when certain linked decisions can be made. This threshold indicates that 90% of the linked crime pairs are correctly classified. However, when this lenient threshold was applied, it resulted in a false alarm rate of 46.70%. This indicates that almost half of the crime pairs were incorrectly classified as linked when applying a hit rate (sensitivity) of 90%, which could be a waste of limited state resources to fully investigate (Burrell *et al*., 2024).

Although it is unlikely that this threshold is used in practice due to limited time and resources, it could be considered by investigators or criminologists conducting a comparative case analysis or pairwise linking task when scanning a database for crime scenes which have behavioural similarities (Ewanation *et al*., 2023; Rainbow, 2015). This of course would not be recommended at later stages of the investigation but rather, for example, when criminologists are scanning cases for potential crime pairs which could be explored further, to determine whether they could be part of a murder series. In particular, unsolved crime pairs which have Jaccard's coefficient values of 0.26 in close geographical and spatial proximities should be considered due to offenders operating in familiar geographical and spatial patterns (Berezowski *et al*., 2023; Canter & Larkin, 1993). Therefore, this threshold could be used to generate new leads to identify a possible suspect.

Following what previous researchers have referred to as the 'ideal' cut off point (Pakkanen *et al*., 2021; Woodhams & Labuschagne, 2012a), the researcher selected Youden's index as the 'mid-range' threshold. Youden's index maximising hit and minimising false alarms which is why it is often referred to as the optimal or ideal cut off point however, Ewanation *et al*. (2023) argue against it stating that crime linkage researchers should refrain from referring to Youden's index as the ideal or optimal cut off point, as base rates and cost versus benefit of linking crime are unknown. Therefore, when implementing Youden's index as the 'mid-range' threshold when all data were considered, Youden's index corresponded with a Jaccard's coefficient of 0.27. This resulted in a hit rate (sensitivity) of 80.91% and a false alarm rate (1-specificity) of 22.94%. The hit rate in the current study is similar to the hit rate of Pakkanen *et al*. (2021) study (85.3%), when Youden's index was applied to their sample of serial murder offences.

This threshold could serve as an *investigative link*, which is when cases share similar crime scene behaviours that may serve to inform the allocation of investigative resources, yet they

are not necessarily unique or distinct to crimes committed by a different offender (Turvey, 2012b). This suggests that crime pairs which have a Jaccard's coefficient above 0.27 could be considered linked. Although this is not considered a necessarily high similarity score (Jaccard's coefficient) between crime pairs, it is consistent with findings from previous research studies (J = 0.24, Davidson & Petherick, 2021). As indicated by the PPV, only 24% of the linked crimes were crime pairs committed by the same offender for all data (solved and unsolved) series, almost half (45%) for solved cases, and just less than a quarter (24%) for unsolved cases.

This suggests that criminologists and investigators examine cases which have Jaccard's coefficients above 0.26 for unsolved cases, to determine whether series can be included or should be excluded based on behavioural evidence which demonstrate not only similarities, but also dissimilarities (Woodhams *et al*., 2019). In addition, geographical locations will also be highly beneficial in this regard as research indicates that serial murder offenders operate in spatial and geographical circumferences which are familiar to them (Berezowski *et al*., 2023; Canter & Larkin, 1993; Snook *et al*., 2004; Snook *et al*., 2005a). Furthermore, when considering the context of South African serial murder offenders, the offenders are often on foot due to low socio-economic status' of not owning a vehicle, as well as luring vulnerable victims to secluded locations with the false offer of employment (Labuschagne, 2021; Salfati *et al*., 2015a). This means that they may often select and choose locations which are familiar to them.

Mirroring previous crime linkage research, a strict threshold with a 15% false alarm rate was applied (Davidson & Petherick, 2021; Woodhams *et al*., 2019) and could serve as a suggested *probative link*. A probative link is referred to as crime scenes which have limited behavioural dissimilarities, and a signature which is shared across crimes (Turvey, 2012b). Results indicate that within the solved dataset, there were 365 incorrect linkages made, and 150 incorrect linkages within the unsolved data set. In total, there were 1105 incorrectly linked decisions made when all data was considered (both solved and unsolved series). While the DE of the model was 84% for all data and 83% for solved, and unsolved data, the misclassification rate for all data was 16%, and 17% for both solved and unsolved datasets. In terms of linked crime pairs perpetrated by the same offender, 29% of cases were found for all data when a strict threshold of 15% FA was applied, 51% for all solved data, and 33% for all unsolved data. This suggests that despite a series being classified as linked, fewer

crime pairs were committed by the same offender for unsolved data. As a result of these errors, the researcher took the analysis a step further, following recommendations from Woodhams *et al*. (2019) and Ewanation *et al*. (2023), who suggested that a more stringent threshold is needed in practice.

5.4.2.2 Trial Phase

For the trial phases and legal proceedings, a very stringent or strict threshold is necessary due to the serious implications of a false conviction. Therefore, a false alarm rate of 5% was implemented following Tonkin *et al*. (2017) study. This very stringent threshold could also be referred to as a *substantial link*. A substantial link is when there are behavioural similarities, dissimilarities, and a signature across crimes (Turvey, 2012b). While the model correctly classified 92% of cases for all data, 89% for solved data, and 91% for unsolved data, results indicated that there were still 359 incorrect linkages made between crime pairs when all data was considered, 127 for all solved data, and 48 incorrect linkages made for all unsolved data. In addition, 277 linked crime pairs were incorrectly classified as unlinked (false negatives/missed linkages) for all data, 211 for all solved data, and 50 for all unsolved data. This is crucial to consider, as despite displaying 'excellent' discrimination accuracy, there are still errors which can have a significant impact on an individual's life if they are falsely convicted for a crime which they did not commit (Brooks & Greenberg, 2021; Sorochinski, 2024; Sorochinski *et al*., 2023). There is also the risk that if the true offender of a crime is not correctly connected to a case, this could result in the offender committing further offences, causing further harm (Davies & Woodhams, 2019). Therefore, as Turvey and Freeman (2012a) poignantly state, although crime linkage is possible, it is hardly absolute nor certain.

The PPV indicates that for unsolved cases, 53% of those that were correctly classified as linked are in fact crime pairs committed by the same offender whereas 72% of linked crime pairs were committed by the same offender for solved cases. A very strict threshold corresponded with a Jaccard's coefficient of 0.35 for all data, 0.34 for all solved data, and 0.37 for all unsolved data. The results indicate that values of Jaccard's similarity coefficients do not necessarily display high levels of similarity and follows previous findings of crime linkage research when examining behavioural similarity scores using Jaccard's similarities coefficient (Davidson & Petherick, 2021; Ewanation *et al*., 2023).

A potential result of not correctly connecting or linking a series is that the offender avoids justice and is free to commit more crimes on further victims (Woodhams *et al*., 2019). There was a higher DE for all unsolved data, which is positive for law enforcement, as there were fewer errors associated with unsolved series. However, it is important to consider that only forensically linked crimes were considered for unsolved series and therefore, the offender may have committed more crimes which were excluded from the study which could impact on the results in practice. This is a shortcoming and limitation, as unsolved serial offenders may display differences in behaviours exhibited across crimes, which are not captured in the current study. However, this threshold level could be considered during the trial phase when providing a decision to prosecutors on when to charge and indict an offender, for court and legal proceedings. Furthermore, this threshold could for example, be provided when presenting similar fact evidence such as behavioural evidence when evidence is submitted to the courts (Ewanation *et al*., 2023; Pakkanen *et al*., 2015a; Tonkin *et al*., 2017).

These findings highlight that, although statistical analysis may assist and guide law enforcement in determining which behaviours to consider and/or when to consider a linkage decision, there are still errors, and behavioural evidence is not an exact science (Turvey & Freeman, 2012a). This is important to consider, and the experience of investigators should be used to decipher both similarities as well as dissimilarities of behavioural evidence displayed at the crime scene. Therefore, it is recommended that a combination of both practitioners, and the use of statistical models, is preferable as despite statistical models, there are still linkage errors (Woodhams *et al*., 2019).

The courts often seek evidence for the admissibility of crime linage which meets the *Daubert standards*, when deciding to use a form of expert evidence (Pakkanen *et al*., 2015a; Woodhams *et al*., 2019). Part of meeting these standards is to provide error rates (Pakkanen *et al*., 2015a). In legal and court proceedings, applying a strict threshold is important in order to establish a highly probable (95%) certainty that the same offender is responsible for the linked crimes, especially when forensic evidence may be lacking as DNA tests are costly and time consuming (Davies & Woodhams, 2019; Labuschagne, 2015b; Woodhams *et al*., 2019). However, investigators and experts in the field should state that there are still a number of error rates, and false alarms, despite the high hit and correct classification rate. The implications of incorrectly linking cases to a series of murders not only impacts the convicted person as well as their family due to the stigma of being classified as a serial

murderer (Sorochinski, 2024; Sorochinski *et al*., 2023). It also provides further opportunity for the actual perpetrator to commit further crimes (Woodhams *et al*., 2019). In South Africa, DNA results can take months to be made available to the SAPS due to high backlog of cases (over 250 000 were reported in 2023) (Ngcobo, 2024), which is still a continuing problem as of 2025 (Parliament of South Africa, 2025). Degradation of forensic evidence due to the environment and circumstances related to each case, such as a delay in body recovery, as well as lack of resources within South Africa, contribute to a delay in solving cases based on forensic evidence (Salfati *et al*., 2015a; Sorochinski *et al*., 2015).

Despite the many unknowns in murder series, the findings of this study offer practical guidance for investigators and crime linkage researchers, highlighting the effects of different thresholds applied, and how they can impact and enhance investigation and court proceedings through the validity of crime linkage research. By continuing to explore these various aspects, more robust methods for examining crime linkage research can assist in refining and ultimately improve on the effectiveness of investigations of serial murders. The research findings enhance and contribute towards understanding crime linkage principles while emphasising and highlighting the importance of the future research in specific areas in order to address some of the limitations of the study. While statistics are useful in providing direction to investigators and narrowing down the number of cases to examine, the results of the study indicate that errors can be made. The researcher suggests that it is therefore necessary for investigators and crime scene analysts to combine their experience in addition to utilising quantitative data, as it is important to identify behavioural similarities, as well as behavioural dissimilarities in cases, which may be important in determining when to link or exclude a crime as belonging to a series. Further discussion is necessary with the SAPS to determine how to implement these findings, and the most feasible way to do so.

5.5 CHAPTER CONCLUSION

This chapter discussed the findings of the results of the research study which found support for the underlying principles of crime linkage. By examining similarity and discrimination accuracy through the research objectives, this research provides support for the underlying principles of crime linkage in a sample of South African murder series. Through testing the effectiveness and/or ineffectiveness of functional behavioural domains, the researcher identified variability in the data which indicates that not all offenders are consistent and/or

unique in their crime scene behaviours. The findings offer further practical implications of using this approach to crime linkage by providing a range of decision thresholds and resulting decision-making errors. The following chapter concludes the study and addresses limitations of the current research, as well as providing recommendations for future studies to consider in the field of crime linkage research.

CHAPTER 6: CONCLUSION

6.1 CHAPTER PREVIEW

This chapter concludes the study and revisits the purpose of the study through the research aim and objectives, followed by a presentation of the key findings of the research. The significance of the study is highlighted, as well as the overall implications of the findings for investigative psychology and crime linkage research. Limitations of the study are acknowledged before recommendations and opportunities for future research are suggested. A final reflection from the researcher is provided regarding the value of the study, before the chapter is concluded.

6.2 PURPOSE OF THE STUDY REVISITED

This study set out to determine whether behaviour consistency and distinctiveness exists among serial murder offenders in South Africa, as it has been hypothesised that serial offenders are consistent, yet distinct, in their crime scene behaviour (Melnyk *et al*., 2011; Pakkanen *et al*., 2021; Santtila *et al*., 2008). Following previous crime linkage research, the study utilised quantitative measures to determine behaviour consistency and distinctives using Jaccard's coefficient, and logistic regression with supplementary ROC and AUC graphs (Bennell *et al*., 2014; Pakkanen *et al*., 2021; Woodhams *et al*., 2019). Therefore, the overarching aim of this study was to test the underlying principles of crime linkage research, namely behavioural consistency and distinctiveness, using solved and unsolved murder series.

Additionally, the researcher compared behaviour similarity and distinctiveness between solved and unsolved murder series to determine whether the assumptions of crime linkage hold true for unsolved murder series. This addressed concerns regarding the ecological validity of samples used in previous crime linkage studies (Pakkanen *et al*., 2021). Furthermore, the researcher sought to determine whether certain functional behavioural domains are effective at linking crimes, or whether it is more effective to include all MO behaviours. Various decision thresholds were applied to the logistic regression model using "if then" scenarios, to determine performance outcomes and error rates. This is of particular importance when providing similar-fact evidence before a court (Davies *et al*., 2019).

6.2.1 Behaviour Consistency and Distinctiveness

The study found that South African serial murder offenders display behavioural similarity and distinctiveness, which provides further empirical support for the underlying principles of crime linkage. Behavioural similarity was quantified using Jaccard's coefficient which established that linked crime pairs displayed significantly higher similarity scores than unlinked crime pairs in all sets of data. This suggests that offenders are consistent in their crime scene behaviour, as they displayed similar behaviours across crimes (Bennell & Canter, 2002). However, the minimum and maximum Jaccard's coefficient scores did show variability in the data, which indicates that some offenders are not as consistent as others. The results of the logistic regression model displayed excellent discrimination accuracy as demonstrated by the ROC and supplementary AUC values. This indicates that linked crime pairs can effectively be distinguished from unlinked crime pairs (Woodhams *et al*., 2019). As a result, these findings illustrate that serial murder offenders in South Africa are unique and distinct in their crime scene behaviours and can be differentiated from one another.

Applying various decision thresholds to the data was important in order to determine error rates and performance metrics to better inform investigators when a linkage decision can be made. While previous studies have typically only explored one specific threshold, such as applying Youden's index, this study demonstrated the results and outcomes of various decision thresholds and the implications thereof. The results of the performance metrics indicate that, despite the model's ability to demonstrate excellent discrimination accuracy, there were still a number of incorrect linkage decisions. This demonstrates that the principles of crime linkage are not applicable to all offenders, and incorrect linkages can be made (Woodhams *et al*., 2019).

Not only are these findings important for informing investigators when deciding to pool resources and 'link' cases based on crime scene behaviours, but it is also crucial for experts when presenting similar fact evidence in court (Pakkanen *et al*., 2015a). Statistically analysing and determining error rates and performance outcomes based on decision thresholds applied, has important implications for law enforcement officials such as investigators to consider when deciding whether or not to link an offender to a crime. Furthermore, these performance outcomes and error rates are necessary in court proceedings when similar fact evidence, such as crime linkage, is presented (Woodhams *et al*., 2019).

6.2.2 Solved versus Unsolved

The findings of this study further contribute towards the ecological validity of crime linkage research by including unsolved murder series. This approach has not been done before, and addresses limitations of previous crime linkage research examining serial murder, which only utilised solved series. If unsolved series displayed significantly lower levels of similarity and distinctiveness, the results would impact the interpretation of findings of previous crime linkage research (Woodhams *et al*., 2019; Woodhams & Labuschagne, 2012a). As found within the solved murder series, linked crime pairs were significantly different to unlinked crime pairs within the unsolved murder series. This indicates that serial murder offenders are consistent across crimes, regardless of whether law enforcement have linked and/or solved the case.

Interestingly, unsolved murder series displayed a higher AUC compared to the solved murder series when all MO behaviours were included however, the difference was not significant. This is an important finding and provides further support for the underlying principles of crime linkage research, as it has been previously suggested that solved murder series are more similar, and thus easier to link and, therefore, solve (Bennell & Jones, 2005). This is a valuable finding for law enforcement as it supports the notion that the principles of crime linkage can be applied and used in investigations. Additional comparison between solved and unsolved behavioural domains interestingly displayed higher AUCs for unsolved target selection domain and unsolved sexual behaviour domain. However, the sexual behavioural domain remained 'ineffective' at discriminating between linked and unlinked crime pairs, regardless of whether the cases were solved or not.

6.2.3 Functional Behavioural Domain Effectiveness

The study further examined whether certain functional behavioural domains were more or less effective at linking crimes in comparison to all MO behaviours. The results suggest that the target selection domain and crime scene dynamics domain were effective at distinguishing between linked and unlinked crime pairs. However, sexual behavioural domain as well as violence and control behavioural domain were ineffective at distinguishing between linked and unlinked crime pairs. This does not suggest that sexual behaviours and violence and control behaviours should be excluded or disregarded, as they contribute towards the excellent discrimination accuracy found overall (as indicated by the

AUC), when all MO behaviours were analysed. Therefore, the results indicate that a combination of all crime scene behaviours was more effective at identifying linked versus unlinked crime pairs, rather than individual functional behavioural domains.

The researcher suggests that offender-controlled functional behavioural domains, such as target selection and crime scene dynamics, displayed greater similarities (as indicated by the effect size of Jaccard's coefficients between linked and unlinked crime pairs), and were more distinct (as indicated by the AUCs). This suggest that offenders may engage in more pre-planning in these types of behaviours consistent with previous studies on serial murder in South Africa (Sorochinski *et al*., 2015; Salfati *et al*., 2015a; Horning *et al*., 2015). Whereas behavioural domains such as sexual behaviours and violence and control behaviours, are susceptible to influence from external factors such as the interaction with the victim, consistent with findings from previous studies (Bennell *et al*., 2021; Salfati *et al*., 2015a). These functional behavioural domains displayed low levels of effect size of Jaccard similarity coefficient scores between linked and unlinked crime pairs. Furthermore, the models were ineffective at differentiating between crime pairs which were committed by the same offender, and crime pairs which committed by different offenders. This could suggest that these behavioural domains are more likely to represent opportunistic behaviours, as they can be influenced by factors such as resistance from the victim, or disruption from a passer-by (Bennell *et al*., 2021; Salfati *et al*., 2015a).

Therefore, despite demonstrating overall consistency and distinctiveness when all MO crime scene behaviours were examined, variability within functional behavioural domains highlight the variability and versatility among offending behaviour. These findings further demonstrate the difficulty and complexity that investigators and researchers face when inferring the assumed function of serial murderer's crime scene behaviours. As a result, based on the findings of the study, the researcher identified ways in which future research can improve on these findings by addressing some of the limitations identified.

6.3 LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Although this study has successfully demonstrated that behaviour consistency exists among a sample of South African serial murder offenders, it has certain limitations which require consideration. Despite the sample size (n = 21 series) being comparable to other studies

conducted on serial murder offenders *(n* = 15 series, Collaros, 2019; *n* = 13 series, Hodgskiss, 2004; *n* = 11 series, Mouzos & West, 2007; *n* = 23 series, Pakkanen *et al*., 2021; *n* = 23 series, Salfati & Bateman, 2005; *n* = 23 series, Santtila *et al*., 2008; *n* = 25 series, Sorochinski *et al*., 2015; *n* = 19 series, Sorochinski & Salfati, 2010), the sample is still considered relatively small and results should be replicated with a larger sample. Therefore, future research should aim to replicate and incorporate a larger sample, preferably including all serial murder offender cases identified by the IPS. In addition, to further enhance ecological validity, inclusion of once-off murders should be considered, as has been done in large scale studies on serial sexual offences examining the principles of crime linkage (Pakkanen *et al*., 2021; Woodhams *et al*., 2019). It would also be valuable if additional analysis could be conducted on unsolved series first linked through forensic and DNA evidence, and to compare similarity and distinctiveness between unsolved cases which were first linked through MO, as done in Woodhams & Labuschagne (2012a) study on serial rapists. This additional analysis may provide further insight into whether unsolved series identified first through forensic evidence, are less consistent and unique in crime scene behaviours.

In addition, although the findings of the study are generally supportive of crime linkage, there is currently no consistent set of coded variables which are used across crime linkage studies. Therefore, caution should be made when generalising the findings to other countries and across different crime types (Beauregard, 2019; Chopin & Beauregard, 2021a; Sorochinski *et al*., 2015). Furthermore, the data is from a sample of South African murder series and, therefore, the results of the study should be viewed with caution when generalising crime scene behaviours or findings of the study to other countries, due to some aspects which may be unique to the South African context. As a result, inferences and/or frequency of serial murder offenders' crime scene behaviours found within the study are possibly unique to the South African population, and even within this specific sample (Sorochinski *et al*., 2015). For example, as documented in previous research (Labuschagne & Salfati, 2015; Salfati *et al*., 2015a; Sorochinski *et al*., 2015), victim demographics, as well as high levels of unemployment and poverty, impact South African serial murder offender's victim choice, MO, and planning in comparison to other countries such as the USA.

Following previous crime linkage studies, the researcher adopted a pragmatic approach to categorising behaviours into domains, based on their assumed function (Bennell *et al*., 2021; Bennell *et al*., 2014). Freeman and Turvey (2012) state that what is deemed 'common sense'

to an investigator, profiler, or researcher, is not necessarily the same common sense that a serial murderer may infer from a behaviour. Therefore, the researcher further suggests that caution is used when considering functional behavioural domain effectiveness, as a potential limitation is whether the behaviours were optimally operationalised in this study, and whether they reflect the true function of an offender's behaviour. In addition, serial murder offenders often have multiple motives which make it difficult to interpret the meaning or intended function of a behaviour (Deepak & Ramdoss, 2021; Freeman & Turvey, 2012; Knoll *et al*., 2009; Yaksic, 2022). As a result, a potential limitation of the study is the assumed function of behaviours and the way in which they were operationalised, which Bennell *et al*. (2021) argue is a common challenge in crime linkage research. It is further possible that a different researcher would interpret the same behaviours differently, as there are multiple ways of interpreting an inferred function of a behaviour (Bennell *et al*., 2021). For example, restraining a victim might serve the function of control for one offender, and for another offender the behaviour could fulfil the sexual fantasy of another. Furthermore, while a positivist approach allows for the quantifiable and objective analysis, it does not capture the subjective motivations or experiences of the offender. This results in a loss of rich information which could have been obtained through interviews with offenders (Crabbé *et al*., 2008).

Therefore, despite aiming to capture as much information at the time, in hindsight, some of the variables could be explored further, to fully determine how best to capture some of the more idiosyncratic and nuanced nature of crime scene behaviours. It is recommended that future research be conducted to explore whether existing variables can be transformed to improve the model's performance within functional behavioural domains (Bennell *et al*., 2021). For example, examining whether it is more helpful to exclude variables which are susceptible to situational influence, as these behaviours are less likely to be reliable for linking purposes (Bateman & Salfati, 2007; Salfati, 2019; Salfati & Bateman, 2005). Future research should also explore whether theoretically informed predictors are more effective or useful at linking crimes. For example, categorising wounding behaviours into process-oriented versus goal-oriented behaviours, or exploring victim interaction, and the impact on the consistency and distinctiveness of behaviours. In addition, it may be useful for future research to determine whether combining functional behavioural domains together, will be more effective for linking purposes, as well as determining whether individual crime scene behaviours are effective at connecting cases.

Despite Jaccard's similarities and LOOCV binary logistic regression models being the most common approaches to crime linkage research, alternative linking methodologies, computerised decision support tools, and statistical methods, should be explored further (Tonkin & Weeks, 2021). For example, sophisticated tree methodologies, such as Random Forest Algorithms or Adaptive boosting (AdaBoost) multivariate classification tree analysis (Bennell *et al*., 2021; Thongkam *et al*., 2008). The Bayesian approach is known to be more practitioner-orientated and is a model which is likely to be used in future research, as the linkage context can be taken into account, using predetermined probabilities (Bennell *et al*., 2015; Burrell *et al*., 2024; Pakkanen *et al*., 2021; Tonkin *et al*., 2019; Tonkin & Weeks, 2021). Therefore, future research studies should explore additional methodological approaches and compare the results to the current study, to determine whether there are more effective models that can be used for linking purposes.

Lastly, a limitation of the study, and, indeed, one which is found across other crime linkage research, is the class imbalance problem (Ewanation *et al*., 2023; Woodhams *et al*., 2019). The class imbalance problem is emphasised as a challenge found across crime linkage research, as the number of unlinked crime pairs unsurprisingly outweigh the number of linked crime pairs (Bennell *et al*., 2021; Ewanation *et al*., 2023). This class imbalance results in low base rates, which affect decision making errors (Ewanation *et al*., 2023). Although addressing this concern was not within the scope of the current study, the issue is challenging and complex. The cost of not linking an offender to a crime could result in more victims, and lack of closure for victims' families (Alison *et al*., 2002). Conversely, an incorrect linkage made could result in a false conviction, causing suffering to both the falsely convicted individual as well as their family (Sorochinski, 2024; Sorochinski *et al*., 2023). In addition, the true offender goes undetected, and consequentially could result in murdering further victims (Yaksic *et al*., 2021). Therefore, a recommendation for future research is to explore this phenomenon further and conduct a cost-benefit analysis, as recommended in previous research on crime linkage (Ewanation *et al*., 2023; Woodhams *et al*., 2019). Furthermore, it is recommended that the results of the study undergo peer review and be published in scientific journals which is one of the requirements for *Daubert* standards, in order for crime linkage to be admissible in court (Davies *et al*., 2019; Pakkanen *et al*., 2015a).

6.4 VALUE OF THE STUDY

This is the first known study to test the underlying principles of crime linkage on a sample of serial murder offenders which included unsolved (but linked forensically) series. By examining original police case files and through the inclusion of a more ecologically valid sample, this study adds to the validity of the assumptions underlying crime linkage. Testing the principles of crime linkage to determine whether serial murder offenders in South Africa behave in consistent and unique ways, is important for police investigators and helpful for linking crimes as forensic evidence may not be available, or if it is available, is costly and time consuming for results to become available. Therefore, the researcher is confident that this research contributes to the body of knowledge of serial murder offending behaviour in South Africa, as well as to the field of crime linkage research. In particular, this study contributes to the validity of the underlying principles and assumptions of crime linkage by examining serial murder offender's behaviour using an ecologically valid sample, which has important implications for both crime linkage research and law enforcement. The results indicate that serial murderers in South Africa are, overall, consistent in behaviours displayed across crime scenes, and are unique enough so that they can be differentiated from offenders committing similar crimes.

Furthermore, the study adds a significant contribution to the field of crime linkage research by addressing previous limitations of crime linkage research studies which only included solved murder series. This resulted in calling into question the ecological validity of samples used in previous research, and thus questioning the validity of the assumptions of crime linkage research. As a result, this research is the first known study to include unsolved murder series and adds to the ecological validity of crime linkage research, as law enforcement are tasked with investigating and solving unsolved crimes. By examining and comparing unsolved murder series, this study provides a nuanced and unique perspective into serial murder offending behaviour. As a result, this study highlights further discussion and exploration of the behaviour consistency of serial murder offenders, particularly involving unsolved murder series.

On a practical level, through testing the underlying principles of crime linkage research, the researcher provides support for the behaviour consistency hypothesis of serial murder offenders. By determining the effectiveness of linking crimes through examining behaviour

similarity and distinctives using all MO behaviours, or through functional behavioural domains, the researcher was able to determine that it is more useful and effective for investigators to consider all MO behaviours, rather than specific functional behavioural domains when linking crimes. Behaviours which are considered within the control of the offender, such as target selection and crime scene characteristics, are more effective at distinguishing between linked and unlinked crime pairs. However, behaviours which are impacted by the victim interaction and are more susceptible to external factors, such as sexual behaviours and violence and control behaviours, are less likely to be differentiated between linked and unlinked crime pairs. In addition, the findings of the study, such as variability within functional behavioural domains, highlight that not all serial murder offenders display behaviour consistency and/or unique behaviours across domains. This provides further support for the effectiveness of linking offenders when examining all crime scene MO behaviours, rather than linking offenders based on functional behavioural domains.

Lastly, the study demonstrated that investigators could apply thresholds at different stages of the investigation to decide whether to pursue or link a case, based on the crime scene behaviour Jaccard's similarity coefficient. Another practical implication is the use of expert testimony in court which can refer to this type of study in order to validate the underlying principles of crime linkage research and provide error rates to the courts. Providing error rates is one of the requirements of the *Daubert standards* which is important for crime linkage if it is considered to be as admissible in court as a form of expert testimony (Pakkanen *et al*., 2015a; Woodhams *et al*., 2019). While serial murder is a morbid curiosity, it is important for researchers to provide studies which are helpful to law enforcement and conducive to the apprehension of offenders, preventing further harm to victims (Chopin & Beauregard, 2021b; Turvey & Freeman, 2012b; Yaksic *et al*., 2019). The researcher trusts that this study facilitates interest in investigating the behaviour of serial murder offenders using the principles of crime linkage. The researcher is confident that this research is beneficial to the field of crime linkage, opening the pathway in examining unsolved murder series.

6.5 CHAPTER CONCLUSION

This chapter concluded the research study and succinctly presented the main findings of the study which found empirical support for two underlying assumptions and principles of crime linkage namely, behaviour consistency and distinctiveness. By examining similarity and discrimination accuracy through the research objectives, this research provided support for the underlying principles of crime linkage in a sample of South African murder series. However, the results indicated that, despite overall consistency of serial murder offender's behaviour, there was variability in the data which demonstrated that not all serial murder offenders were consistent. The findings offered further practical implications of using this approach to crime linkage by providing a range of decision thresholds and resulting decision-making errors due to low base rates of linked crime pairs. The limitations of the study were presented, and potential areas from which future research studies can improve on these findings, were addressed. Lastly, the value of the study was highlighted, indicating that this was the first study to include unsolved murder series when examining behaviour consistency and distinctiveness of serial murder offenders, thereby enhancing ecological validity of crime linkage research.

REFERENCES

Aamodt, M. G., Leary, T., & Girimurugan, S. (2023). *Radford/FGCU Annual Report on Serial Killer Statistics: 2023.* Radford, VA: Radford University.

Aamodt, M. G, Leary, T., & Southard, L. (2020). *Radford/FGCU Annual Report on Serial Killer Statistics: 2020*. Radford, VA: Radford University.

Ackerman, J. M., & Rossmo, D. K. (2015). How far to travel? A multilevel analysis of the residence-to-crime distance. *Journal of Quantitative Criminology*, *31*(2), 237–262.

Acorn, A. E. (1991). Similar fact evidence and the principle of inductive reasoning: Making sense. *Oxford Journal of Legal Studies, 11*(1), 63-91.

Adjorlolo, S., & Chan, H. C. O. (2014). The controversy of defining serial murder: Revisited. *Aggression and Violent Behavior*, *19*(5), 486–491.

Aebi, M. (2010). Methodological issues in the comparison of police-recorded crime rates. In S. G. Shoham, P. Knepper, & M. Kett (Eds.), *International Handbook of Criminology* (pp. 237–254). New York: Routledge.

Ainsworth, P. B. (2000). Crime analysis and offender profiling. In P. B. Ainsworth (Ed.), *Psychology and crime: Myths and reality* (pp. 102–120). London: Routledge.

Alison, L., Bennell, C., Mokros, A., & Ormerod, D. (2002). The personality paradox in offender profiling: A theoretical review of the processes involved in deriving background characteristics from crime scene actions. *Psychology, Public Policy, and Law*, *8*(1), 115–135.

Alison, L., Goodwill, A., Almond, L., Van Den Heuvel, C., & Winter, J. (2010). Pragmatic solutions to offender profiling and behavioural investigative advice. *Legal and Criminological Psychology*, *15*(1), 115–132.

Alison, L., Smith, M. D., Eastman, O., & Rainbow, L. (2003). Toulmin's philosophy of argument and its relevance to offender profiling. *Psychology, Crime and Law*, *9*(2), 173–183.

Allely, C. S., Minnis, H., Thompson, L., Wilson, P., & Gillberg, C. (2014). Neurodevelopmental and psychosocial risk factors in serial killers and mass murderers. *Aggression and Violent Behavior*, *19*(3), 288–301.

American Psychological Association. (2016). Ethical principles of psychologists and code of conduct (2002 as amended 2010). *American Psychologist*, *71*(900).

Barenbaum, N. B., & Winter, D. G. (2008). History of modern personality theory and research. In O. P. John, R. W. Robins, & L. A. Pervin (Eds.), *Handbook of personality* (3rd ed., pp. 3–26). New York, NY: The Guildford Press.

Barkhuizen, J. (2006). *An exploration of the intrapsychic development and personality structure of serial killers through the use of psychometric testing* (Unpublished Master's dissertation). University of Pretoria, Pretoria.

Bateman, A. L, & Salfati, C. G. (2007). An examination of behavioral consistency using individual behaviors or groups of behaviors in serial homicide. *Behavioral Sciences and the Law*, *25*(4), 527–544.

Beauregard, E. (2019). Sexual homicide: The need for an international examination of the crime scene. *International Journal of Offender Therapy and Comparative Criminology*, *63*(9), 1503–1516.

Beauregard, E., & Bouchard, M. (2010). Cleaning up your act: Forensic awareness as a detection avoidance strategy. *Journal of Criminal Justice*, *38*(6), 1160–1166.

Beauregard, E., Chopin, J., & Andresen, M. (2022). Modus operandi in sexual assaults of female strangers does not change over time. *Sexual Abuse*, *35*(5), 596-623.

Beauregard, E., & Martineau, M. (2014). No body, no crime? The role of forensic awareness in avoiding police detection in cases of sexual homicide. *Journal of Criminal Justice*, *42*(2), 213–220.

Bennell, C. (2005). Improving police decision making: General principles and practical applications of receiver operating characteristic analysis. *Applied Cognitive Psychology*, *19*(9), 1157–1175.

Bennell, C., Bloomfield, S., Emeno, K., & Musolino, E. (2013). Classifying serial sexual murder/murderers: An attempt to validate Keppel and Walter's (1999) model. *Criminal Justice and Behavior*, *40*(1), 5–25.

Bennell, C., Bloomfield, S., Snook, B., Taylor, P., & Barnes, C. (2010). Linkage analysis in cases of serial burglary: Comparing the performance of university students, police professionals, and a logistic regression model. *Psychology, Crime and Law*, *16*(6), 507–524.

Bennell, C., & Canter, D. V. (2002). Linking commercial burglaries by modus operandi: Tests using regression and ROC analysis. *Science & Justice*, *42*(3), 153–164.

Bennell, C., Goodwill, A. M., & Chinneck, A. (2015). Informing practice: Research methods in crime linkage analysis. In J. Woodhams & C. Bennell (Eds.), *Crime Linkage, Theory Research, and Practice* (pp. 337–367). Boca Raton, FL: CRC Press Taylor & Francis Group.

Bennell, C., & Jones, N. J. (2005). Between a ROC and a hard place: A method for linking serial burglaries by modus operandi. *Journal of Investigative Psychology and Offender Profiling*, *2*(1), 23–41.

Bennell, C., Jones, N. J., & Melnyk, T. (2009). Addressing problems with traditional crime linking methods using receiver operating characteristic analysis. *Legal and Criminological Psychology*, *14*(2), 293–310.

Bennell, C., Mugford, R., Ellingwood, H., & Woodhams, J. (2014). Linking crimes using behavioural clues: Current levels of linking accuracy and strategies for moving forward. *Journal of Investigative Psychology and Offender Profiling*, *11*(1), 29–56.

Bennell, C., Mugford, R., Woodhams, J., Beauregard, E., & Blaskovits, B. (2021). Linking serial sex offences using standard, iterative, and multiple classification trees. *Journal of Police and Criminal Psychology*, *36*(4), 691–705.

Bennell, C., Snook, B., MacDonald, S., House, J. C., & Taylor, P. J. (2012). Computerized crime linkage systems: A critical review and research agenda. *Criminal Justice and Behavior*, *39*(5), 620–634.

Bennell, C., Snook, B., Taylor, P. J., Corey, S., & Keyton, J. (2007). It's no riddle, choose the middle: The effect of number of crimes and topographical detail on police officer predictions of serial burglars' home locations. *Criminal Justice and Behavior*, *34*(1), 119–132.

Bennell, C., & Woodhams, J. (2015). Crime linkage research: Where to from here? In J. Woodhams & C. Bennell (Eds.), *Crime Linkage Theory, Research, and Practice* (pp. 369–372). Boca Raton, FL: CRC Press.

Berezowski, V., MacGregor, D., Ellis, J., Moffat, I., & Mallett, X. (2023). More than an offender location tool: Geographic profiling and body deposition sites. *Journal of Police and Criminal Psychology*, *38*(1), 3–19.

Boberg, U. (1957). *The Boberg Story*. Cape Town: Howard Rimmins (Pty.) Ltd.

Borg, A., & Boldt, M. (2016). Clustering residential burglaries using modus operandi and spatiotemporal information. *International Journal of Information Technology and Decision Making*, *15*(1), 23–42.

Bougard, N. B., & Hesselink, A. (2021). Child sexual abuse in South Africa: A criminological case study analysis exploring a life-course-persistent pathway for serial rape and murder. *Journal of Asian and African Studies*, *57*(5), 945–963.

Brooks, S. K., & Greenberg, N. (2021). Psychological impact of being wrongfully accused of criminal offences: A systematic literature review. *Medicine, Science, and the Law*, *61*(1), 44–54.

Buil-Gil, D., Pina-Sánchez, J., & Aebi, M. F. (2025). The effect of counting rules on cross-national comparisons of homicide. *CrimRxiv*.

Bull, R. (2019). Roar or "peace": Is it a tall story? In R. Bull & I. Blandón-Gitlin (Eds.) *The Routledge International Handbook of Legal and Investigative Psychology*, 1–343. Routledge.

Burgess, A. W., Hartman, C. R., Ressler, R. K., Douglas, J. E., & McCormack, A. (1986). Sexual homicide: A motivational model. *Journal of Interpersonal Violence*, *1*(3), 251–272.

Burrell, A. (2022). Behavioural crime linkage. In *Robbery: The Tipping Point Between Theft and Violence* (pp. 69–96). Cham: Springer International Publishing.

Burrell, A., Bull, R., & Bond, J. (2012). Linking personal robbery offences using offender behaviour. *Journal of Investigative Psychology and Offender Profiling*, *9*(3), 201–222.

Burrell, A., Costello, B., Hobson, W., Morton, R., Muñoz, C. G., Thomas, K., & Kloess, J. A. (2023). Being prepared for emotionally demanding research. *Communications Psychology*, *1*(1), 9.

Burrell, A., Costello, B., & Woodhams, J. (2024). Methods used to link crimes using behaviour: A literature review. *Aggression and Violent Behavior*, 79, 102014.

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D., & Walker, K. (2020). Purposive sampling: complex or simple? Research case examples. *Journal of Research in Nursing*, *25*(8), 652–661.

Canter, D. V. (1994). *Criminal shadows: Inside the mind of the serial killer*. London: HarperCollins.

Canter, D. V. (1995). Psychology of offender profiling. In R. Bull & D. Carson (Eds.), *Handbook of psychology in legal contexts* (pp. 343–355). Chichester, England: Wiley.

Canter, D. V. (2000). Offender profiling and criminal differentiation. *Legal and Criminological Psychology*, *5*(1), 23–46.

Canter, D. V. (2002). The violated body. In *The Body* (pp. 57–75). Cambridge, UK: Cambridge University Press.

Canter, D. V. (2004). Offender profiling and investigative psychology. *Journal of Investigative Psychology and Offender Profiling*, *1*(1), 1–15.

Canter, D. V. (2010). *Forensic Psychology: A very short introduction*. New York, NY: Oxford University Press.

Canter, D. V., Alison, L. J., Alison, E., & Wentink, N. (2004). The organized/disorganized typology of serial murder: Myth or model? *Psychology, Public Policy, and Law*, *10*(3), 293–320.

Canter, D. V., Coffey, T., Huntley, M., & Missen, C. (2017). Predicting serial killers' home base using a decision support system. *Applications of Geographical Offender Profiling*, 165–184.

Canter, D. V., & Larkin, P. (1993). The environmental range of serial rapists. *Journal of Environmental Psychology*, *13*(1), 63–69.

Canter, D. V., & Wentink, N. (2004). An empirical test of Holmes and Holmes's serial murder typology. *Criminal Justice and Behavior*, *31*(4), 489–515.

Canter, D. V., & Youngs, D. (2003). Beyond 'offender profiling': The need for an investigative psychology. *Handbook of Psychology in Legal Contexts*, 171–205.

Castle, T., & Hensley, C. (2002). Serial killers with military experience: Applying learning theory to serial murder. *International Journal of Offender Therapy and Comparative Criminology*, *46*(4), 453–465.

Chai, A. M. M., Beauregard, E., & Chopin, J. (2021). "Drop the body": Body disposal patterns in sexual homicide. *International Journal of Offender Therapy and Comparative Criminology*, *65*(6–7), 692–714.

Chai, A. M. M., Rossmo, K. D., Chopin, J., & Yaksic, E. (2024). The math of serial murder: Understanding victim numbers and series duration. *Journal of Criminal Justice*, 91, 102164.

Chai, A. M. M., Yaksic, E., & Chopin, J. (2022). One "two" many: An examination of solo perpetrator versus team perpetrator serial homicides. *Homicide Studies*, *26*(2), 176–198.

Chan, H. C., Beauregard, E., & Myers, W. C. (2015). Single-victim and serial sexual homicide offenders: Differences in crime, paraphilias and personality traits. *Criminal Behaviour and Mental Health*, *25*(1), 66–78.

Charan, J. L. (2023). A retrospective analytical study of forensic evidence in rape and murder cases and its implications on judicial outcomes in India. *Journal of Forensic Science and Medicine*, *9*(2), 167–176.

Chopin, J., & Aebi, M. F. (2019). The tree that hides the forest? Testing the construct validity of ViCLAS through an empirical study of missing data. *Policing: A Journal of Policy and Practice*, *13*(1), 55–65.

Chopin, J., & Beauregard, E. (2021a). Sexual homicide in France and Canada: An international comparison. *Journal of Interpersonal Violence*, *36*(19–20), NP10453–NP10476.

Chopin, J., & Beauregard, E. (2021b). Sexual homicide and its investigation: New perspectives to improve police practices. *Criminal Investigations of Sexual Offenses*, 235–251.

Chopin, J., & Beauregard, E. (2024). How to get away with (sexual) murder? Unraveling cold cases in sexual homicide using a hybrid modeling probabilistic approach. *Behavioral Sciences and the Law*, *42*(4), 293–312.

Chopin, J., Beauregard, E., & Bitzer, S. (2020). Factors influencing the use of forensic awareness strategies in sexual homicide. *Journal of Criminal Justice, 71,* 101709.

Chopin, J., Beauregard, E., Bitzer, S., & Reale, K. (2019). Rapists' behaviors to avoid police detection. *Journal of Criminal Justice, 61,* 81–89.

Chopin, J., Paquette, S., & Beauregard, E. (2022). Is there an "expert" stranger rapist? *Sexual Abuse: Journal of Research and Treatment*, *34*(1), 78–105.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, 20(1), 37–46.

Cohen, J. (1962). The statistical power of abnormal-social psychological research: A review. *Journal of Abnormal and Social Psychology*, *65*(3), 145–153.

Collaros, D. (2019). *Exploring the psychogeography of serial murderers in South Africa* (Unpublished PhD thesis). University of the Witwatersrand, Johannesburg.

Cooper, G. S., & Meterko, V. (2019). Cognitive bias research in forensic science: A systematic review. *Forensic Science International*, *297,* 35–46.

Crabbé, A., Decoene, S., & Vertommen, H. (2008). Profiling homicide offenders: A review of assumptions and theories. *Aggression and Violent Behavior*, *13*(2), 88–106.

Curtis-Ham, S., Bernasco, W., Medvedev, O. N., & Polaschek, D. L. L. (2021). A national examination of the spatial extent and similarity of offenders' activity spaces using police data. *ISPRS International Journal of Geo-Information*, *10*(2), 47.

DATAtab Team (2024). *DATAtab: Online Statistics Calculator*. DATAtab e.U. Graz, Austria. Available at: https://datatab.net.

Davidson, S., & Petherick, W. (2021). Case linkage in Australian serial stranger rape. *Journal of Criminological Research, Policy and Practice, 7*(1), 4–17.

Davies, K., Imre, H., & Woodhams, J. (2021). The utility of the Violent Crime Linkage Analysis System for conducting comparative case analysis. *Journal of Criminological Research, Policy and Practice, 7*(1), 77-90.

Davies, K., Tonkin, M., Bull, R., & Bond, J. W. (2012). The course of case linkage never did run smooth: A new investigation to tackle the behavioural changes in serial car theft. *Journal of Investigative Psychology and Offender Profiling*, *9*(3), 274–295.

Davies, K., & Woodhams, J. (2019). The practice of crime linkage: A review of the literature. *Journal of Investigative Psychology and Offender Profiling*, *16*(3), 169–200.

Davies, K., Woodhams, J., & Rainbow, L. (2018). Crime linkage and sexual homicide. In J. Proulx, E. Beauregard, A. Carter, A. Mokros, R. Darjee, & J. James (Eds.), *Routledge International Handbook of Sexual Homicide Studies* (pp. 527–543). London: Routledge.

Davies, K., Woodhams, J., & Tonkin, M. (2019). Reviewing the use of crime linkage evidence within a legal context. In *The Routledge International Handbook of Legal and Investigative Psychology* (pp. 197-211). Routledge.

De Wet, J. A. (2004). *A psychosocial perspective on the personality development of the serial murderer* (Unpublished Master's thesis). University of Pretoria, Pretoria.

De Wet, J., & Potgieter, C. (2015). Serial murder in South Africa: Asking different questions. *Acta Criminological: Southern African Journal of Criminology*, *28*(1), 77–87.

Deakin, J., Smithson, H., Spencer, J., & Medina-Ariza, J. (2007). Taxing on the streets: Understanding the methods and process of street robbery. *Crime Prevention and Community Safety*, *9*(1), 52–67.

Deepak, S. A. (2021). Serial killings in India: Case studies and profiling strategies. *Criminal Psychology and the Criminal Justice System in India and Beyond*, 133–144.

Deepak, S. A., & Ramdoss, S. (2021). The life-course theory of serial killing: A motivation model. *International Journal of Offender Therapy and Comparative Criminology*, *65*(13–14), 1446–1472.

Del Fabbro, G. A. (2006). *A family system understanding of serial murder* (Unpublished PhD thesis). University of Pretoria, Pretoria.

Douglas, J. E., Burgess, A. W., Burgess, A. G., & Ressler, R. K. (2013). *Crime classification manual: A standard system for investigating and classifying violent crime*. John Wiley & Sons.

Douglas, J. E., & Munn, C. (1992). Violent crime scene analysis: Modus operandi, signature and staging. *FBI Law Enforcement Bulletin*, *61*(2), 1–10.

Douglas, J. E., Ressler, R. K., Burgess, A. W., & Hartman, C. R. (1986). Criminal profiling from crime scene analysis. *Behavioral Sciences & the Law*, *4*(4), 401–421.

Dutta, P., & Banik, A. K. (2023). Crime linkage and psychological profiling of offenders under intuitionistic fuzzy environment using a novel resemblance measure. *Artificial Intelligence Review*, *56*(1), 893–936.

Egger, S. A. (1984). A working definition of serial murder and the reduction of linkage blindness. *Journal of Police Science and Administration*, *12*(3), 348–357.

Egger, S. A. (2002). *The killers among us: An examination of serial murder and its investigation* (2nd ed.). Upper Saddle River, NJ: Prentice-Hall.

Eichinger, M., & Darjee, R. (2021). Sexual homicide in Australia and New Zealand: A description of offenders, offences and victims. *Psychiatry, Psychology and Law*, *28*(6), 885–908.

Ellingwood, H., Mugford, R., Bennell, C., Melnyk, T., & Fritzon, K. (2013). Examining the role of similarity coefficients and the value of behavioural themes in attempts to link serial arson offences. *Journal of Investigative Psychology and Offender Profiling*, *10*(1), 1–27.

Ewanation, L., Bennell, C., Tonkin, M., & Santtila, P. (2023). Receiver Operating Characteristic curves in the crime linkage context: Benefits, limitations, and recommendations. *Applied Cognitive Psychology*, *37*(6), 1277–1289.

Farrell, A. L., Keppel, R. D., & Titterington, V. B. (2013). Testing existing classifications of serial murder considering gender: An exploratory analysis of solo female serial murderers. *Journal of Investigative Psychology and Offender Profiling*, *10*(3), 268–288.

Federal Bureau of Investigation. (2008). *Serial murder: Multi-disciplinary perspectives for investigators*. US Department of Justice, Washington, D.C.

Flynn, S., Ibrahim, S., Tham, S. G., Turnbull, P., Kapur, N., Appleby, L., & Shaw, J. (2024). Multiple homicide: A descriptive study of serial homicide and mass murder in England and Wales. *The Journal of Forensic Psychiatry & Psychology*, *35*(5), 727–743.

Fox, B., & Farrington, D. P. (2018). What have we learned from offender profiling? A systematic review and meta-analysis of 40 years of research. *Psychological Bulletin, 144*(12), 1247–1274.

Fox, J. A., & Levin, J. (2014). *Extreme Killing: Understanding Serial and Mass Murder* (3rd ed.). Los Angeles: Sage Publications, Inc.

Freeman, J., & Turvey, B. E. (2012). Interpreting motive. In B. Turvey (Ed.), *Criminal Profiling: An Introduction to Behavioral Evidence Analysis* (4th ed., pp. 311–329). San Diego: Elsevier.

Fridel, E. E., & Fox, J. A. (2018). Too few victims: Finding the optimal minimum victim threshold for defining serial murder. *Psychology of Violence, 8(*4), 505–514.

Gee, D., & Belofastov, A. (2015). Sex crime linkage: Sexual fantasy and offense plasticity. In J. Woodhams & C. Bennell (Eds.), *Crime Linkage: Theory, research, and practice* (pp. 33–54). Boca Raton, FL: CRC Press.

Goodwill, A. M., Allen, J. C., & Kolarevic, D. (2014). Improvement of thematic classification in offender profiling: Classifying Serbian homicides using multiple correspondence, cluster, and discriminant function analyses. *Journal of Investigative Psychology and Offender Profiling, 11*(3), 221–236.

Gresswell, D. M., & Hollin, C. R. (1994). Multiple murder: A review. *British Journal of Criminology, 34*(1), 1–14.

Grimes, D. A., & Schulz, K. F. (2005). Refining clinical diagnosis with likelihood ratios. *Lancet, 365*(9469), 1500–1505.

Groth, A. N., Burgess, A. W., & Holmstrom, L. L. (1977). Rape: Power, anger, and sexuality. *American Journal of Psychiatry, 134*(11), 1239–1243.

Grubin, D., Kelly, P., & Brundsdon, C. (2001). *Linking serious sexual assaults through behaviour* (No. 215). London Home Office, Research, Development and Statistics Directorate.

Guba, E. G., & Lincoln, Y. S. (2005). Paradigmatic controversies, contradictions, and emerging confluences. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (pp. 191–215). Sage Publications Ltd.

Haggerty, K. (2009). Modern serial killers. *Crime, Media, Culture*, *5*(2), 168–187.

Haggerty, K., & Ellerbrok, A. (2011). The social study of serial killers. *Criminal Justice Matters*, *86*(1), 6–7.

Hanley, J., & McNeil, B. (1982). The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology, 143*(1), 29-36.

Harbort, S., & Mokros, A. (2001). Serial murderers in Germany from 1945 to 1995: A descriptive study. *Homicide Studies*, *5*(4), 311–334.

Harrison, M. A., & Frederick, E. J. (2022). Interested in serial killers? Morbid curiosity in college students. *Current Psychology*, *41*(6), 3768–3777.

Hazelwood, R. R, & Douglas, J. E. (1980). The lust murderer. *FBI Law Enforcement Bulletin*, *49*(4), 18–22.

Hazelwood, R. R, & Warren, J. I. (2003). Linkage analysis: Modus operandi, ritual, and signature in serial sexual crime. *Aggression and Violent Behavior*, *8*(6), 587–598.

Health Professions Council of South Africa (HPCSA). (2004). *Form 223: Professional board for psychology: Rules of conduct pertaining specifically to psychology*. Pretoria, South Africa: HPCSA.

Heide, K. M., & Keeney, B. (1995). Serial Murder: A more accurate and inclusive definition. *International Journal of Offender Therapy and Comparative Criminology*, *39*(4), 299–306.

Hickey, E. W. (2012). *Serial murderers and their victims* (6th ed.). Belmont, CA: Wadsworth.

Hickey, E. W. (2016). *Serial murderers and their victims* (7th ed.). Boston, MA: Cengage Learning.

Hodge, S. (2000). A multivariate model of serial sexual murder. In D. V. Canter & L. J. Alison (Eds.), *Offender profiling series: Profiling Rape and Murder* (Vol. 5, pp. 1–19). Dartmouth: Aldershot.

Hodgkiss, B. (2001). *A multivariate model of the offence behaviours of South African serial murderers* (Unpublished Master's thesis). Rhodes University, Grahamstown.

Hodgskiss, B. (2004). Lessons from serial murder in South Africa. *Journal of Investigative Psychology and Offender Profiling*, *1*(1), 67–94.

Holmes, R. M., & De Burger, J. (1985). Profiles in terror: The serial murder. *Probation, 49*, 29-34.

Holmes, R. M., De Burger, J., & Holmes, S. T. (1988). Inside the mind of the serial murder. *American Journal of Criminal Justice*, *13*(1), 1–9.

Holmes, R. M., & Holmes, S. T. (1998). *Serial murder* (2nd ed.). Thousand Oaks, CA: Sage.

Holmes, R. M., & Holmes, S. T. (2002). *Sex Crimes: Patterns and Behavior* (2nd ed.). Thousand Oaks, CA: Sage.

Holmes, R. M., & Holmes, S. T. (2013). Selected problems in serial murder investigations. *Contemporary Perspectives on Serial Murder*, 227–234.

Horning, A. M, Salfati, C. G., & Labuschagne, G. N. (2015). South African serial homicide: A victim-focused behavioural typology. *Journal of Investigative Psychology and Offender Profiling*, *12*(1), 44–68.

Hosmer, D. W., & Lemeshow, S. (2000). *Applied Logistic Regression* (2nd ed.) New York, NY: Wiley.

Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied Logistic Regression* (3rd ed). Hobokeng, NJ: John Wiley & Sons.

IBM Corp. (2023). *IBM SPSS Statistics for Macintosh* (Version 29.0.2.0). Armonk, NY: IBM Corp.

James, J., Proulx, J., & Lussier, P. (2018). A cross-national study of sexual murderers in France and Canada. In J. Proulx, E. Beauregard, A. J. Carter, A. Mokros, R. Darjee, & J. James

(Eds.), *Routledge International Handbook of Sexual Homicide Studies* (pp. 171–195). New York, USA: Routledge.

Jenkins, P. (1991). Changing perceptions of serial murder in contemporary England. *Journal of Contemporary Criminal Justice*, *7*(4), 210–231.

Keatley, D. A, & Clarke, D. D. (2020). Crime linkage: Finding a behavioral fingerprint using the "path similarity metric". *Journal of Police and Criminal Psychology*, *35*(2), 240–246.

Keatley, D. A., Golightly, H., Shephard, R., Yaksic, E., & Reid, S. (2021). Using behavior sequence analysis to map serial killers' life histories. *Journal of Interpersonal Violence*, *36*(5–6), 2906–2928.

Keeney, B. T., & Heide, K. M. (1994). Gender differences in serial murderers. *Journal of Interpersonal Violence*, *9*(3), 383–398.

Kelleher, M. D., & Kelleher, C. L. (1998). *Murder most rare: The female serial killer*. Westport, CT: Praeger Publishers/Greenwood Publishing Group.

Keppel, R. D. (1995). Signature murders: A report of several related cases. *Journal of Forensic Sciences*, *40*(4), 670-674.

Keppel, R. D. (2000). Investigation of the Serial Offender. *Serial Offenders: Current thoughts, recent findings*, 121-133.

Keppel, R. D., & Birnes, W. J. (2018). *Signature killers: Interpreting the calling cards of serial murderers*. New York: Pocket Books.

Keppel, R. D., & Walter, R. (1999). Profiling killers: A revised classification model for understanding sexual murder. *International Journal of Offender Therapy and Comparative Criminology*, *43*(4), 417–437.

Knight, Z. G. (2007). Sexually motivated serial killers and the psychology of aggression and "evil" within a contemporary psychoanalytical perspective. *Journal of Sexual Aggression*, *13*(1), 21–35.

Knoll, J. L., Ressler, R. K., Hazelwood, R. R., & Burgess, A. W. (2009). Serial homicide. *Wiley Encyclopedia of Forensic Science*. Portsmouth, UK: John Wiley & Sons Ltd.

Kocsis, R. N., Cooksey, R. W., & Irwin, H. J. (2002). Psychological profiling of sexual murders: An empirical model. *International Journal of Offender Therapy and Comparative Criminology*, *46*(5), 532–554.

Kraemer, G. W., Lord, W. D., & Heilbrun, K. (2004). Comparing single and serial homicide offenses. *Behavioral Sciences and the Law*, *22*(3), 325–343.

Krzywinski, M., & Altman, N. (2014). Visualizing samples with box plots. *Nature Methods*, *11*(2), 119–120.

LaBrode, R. T. (2007). Etiology of the psychopathic serial killer: An analysis of antisocial personality disorder, psychopathy, and serial killer personality and crime scene characteristics. *Journal of Interpersonal Violence*, *7*(2), 151–160.

Labuschagne, G. N. (1998). *Serial murder: An interactional analysis* (Unpublished Master's thesis). University of Pretoria, Pretoria.

Labuschagne, G. N. (2001). *Serial murder revisited: A psychological exploration of two South African cases* (Unpublished PhD thesis). University of Pretoria, Pretoria.

Labuschagne, G. N. (2006). The use of a linkage analysis as evidence in the conviction of the Newcastle serial murderer, South Africa. *Journal of Investigative Psychology and Offender Profiling*, *3*(3), 183–191.

Labuschagne, G. N. (2012). The use of a linkage analysis as an investigative tool and evidential material in serial offenses. In K. Borgeson & K. Kuehnle (Eds.), *Serial Offenders: Theory and Practice* (pp. 187–215). Sudbury, MA: Jones & Bartlett Learning, LLC.

Labuschagne, G. N. (2015a). The use of linkage analysis evidence in serial offense trials. In J. Woodhams & C. Bennell (Eds.), *Crime Linkage: Theory, Research, and Practice* (pp. 197–224). New York: Taylor & Francis Group.

Labuschagne, G. N. (2015b). Criminal investigative analysis: An applied perspective. In R. Zinn & S. Dintew (Eds.), *Forensic Legislative principles and investigative practice* (pp. 275–304). Cape Town: Juta & Co.

Labuschagne, G. N. (2017). Stewart ‘Boetie Boer’ Wilken: Serial murder, necrophilia, and cannibalism: A South African case study. In *Understanding Necrophilia: A global multidisciplinary approach* (pp. 411–417). California: Cognella Academic Publishing.

Labuschagne, G. N. (2021). An overview of serial murder and its investigation in South Africa. In H. C. O. Chan & S. Adjorlolo (Eds.), *Crime, Mental Health and the Criminal Justice System in Africa: A Psycho-Criminological Perspective* (pp. 121–148). Switzerland: Springer International Publishing.

Labuschagne, G. N., & Salfati, C. G. (2015). An examination of serial homicide in south Africa: The practice to research link. *Journal of Investigative Psychology and Offender Profiling*, *12*(1), 4–17.

Li, M., Gao, Q., & Yu, T. (2023). Kappa statistic considerations in evaluating inter-rater reliability between two raters: which, when and context matters. *BMC Cancer*, *23*(1), 799.

Machisa, M. T., Jina, R., Labuschagne, G. N., Vetten, L., Loots, L., & Jewkes, R. (2023). Circumstances, policing, and attrition of multiple compared to single perpetrator rape cases within the South African criminal justice system. *Crime Science*, *12*(1), 11.

Markson, L., Woodhams, J., & Bond, J. W. (2010). Linking serial residential burglary: Comparing the utility of modus operandi behaviours, geographical proximity, and temporal proximity. *Journal of Investigative Psychology and Offender Profiling*, *7*(2), 91–107.

Marono, A. J., Reid, S., Yaksic, E., & Keatley, D. A. (2020). A behaviour sequence analysis of serial killers’ lives: From childhood abuse to methods of murder. *Psychiatry, Psychology and Law*, *27*(1), 126–137.

McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemia Medica*, *22*(3), 276-282.

McKinley, A., & Petherick, W. A. (2021). Serial homicide in Australia, 1820-2020. *Salus Journal*, *9*(1), 39–50.

MedCalc (2024) *Statistical Software* (version 19.2.6). Ostend, Belgium: MedCalc Software Ltd. Available at: https://www.medcalc.org

Melnyk, T., Bennell, C., Gauthier, D. J., & Gauthier, D. (2011). Another look at across-crime similarity coefficients for use in behavioural linkage analysis: An attempt to replicate Woodhams, Grant, and Price (2007). *Psychology, Crime and Law*, 17(4), 359–380.

Meloy, J. R., & Felthous, A. R. (2004). Introduction to this issue: Serial and mass homicide. *Behavioural Sciences and the Law*, *22*, 289–290.

Messori, L. (2016). *Frequencies between serial killer typology and theorized etiological factors* (Unpublished PhD thesis). Antioch University, Santa Barbara.

Meyer, C. B. (2007). Criminal profiling as expert evidence? An international case law perspective. In R.N Kocsis (Ed.), *Criminal profiling: International theory, research and practice* (pp. 207–247). Totowa, NJ: Humana Press.

Minkler, M., DeLisi, M., Marquart, J., & Scurich, N. (2024). The dark figure of murder and unsolved homicides in the USA. *Journal of Criminal Psychology*, *14*(4), 484–501.

Mischel, W., & Shoda, Y. (1995). A cognitive-affective system theory of personality: reconceptualizing situations, dispositions, dynamics, and invariance in personality structure. *Psychological Review*, 246–268.

Mokros, A., & Alison, L. J. (2002). Is offender profiling possible? Testing the predicted homology of crime scene actions and background characteristics in a sample of rapists. *Legal and Criminological Psychology*, *7*(1), 25–43.

Morton, R. J., & Hilts, M. (2008). *Serial murder: Multi-disciplinary perspectives for investigators*. Washington, DC: US Department of Justice – Federal Bureau of Investigation.

Morton, R. J., & McNamara, J. J. (2005). Serial murder. *Encyclopedia of Forensic and Legal Medicine*, 47–53.

Mouzos, J, & West, D. (2007). An examination of serial murder in Australia. *Trends & Issues in Crime and Criminal Justice*, *346*, 1–6.

Myburgh, E. (2023). Email correspondence, 29 August.

Nee, C. (2015). Understanding expertise in burglars: From pre-conscious scanning to action and beyond. *Aggression and Violent Behavior*, *20*, 53–61.

Newton, M. (2000). *The encyclopedia of serial killers*. New York: Checkmark Books.

Ngcobo, K. (2024). Crime STATS: Massive DNA backlog finally cleared Cele confirms, *TimesLive*. Available at: https://www.timeslive.co.za/news/south-africa/2024-02-16-crime-stats-massive-dna-backlog-finally-cleared-cele-confirms/. (Accessed 16 October 2024).

Orellana-Campos, C. (2020). Genital injuries: Are they telling us something about sexual violence? *Revista Brasileira de Ginecologia e Obstetrícia*, *42*(2), 106–113.

Osborne, J. R., & Salfati, G. C. (2015). Re-conceptualizing "cooling-off periods" in serial homicide. *Homicide Studies*, *19*(2), 188–205.

Pakkanen, T., Santtila, P., & Bosco, D. (2015a). Crime linkage as expert evidence: Making a case for the Daubert Standard. In J. Woodhams & C. Bennell (Eds.), *Crime Linkage: Theory, Research, and Practice* (pp. 225–249). New York: Taylor & Francis Group.

Pakkanen, T., Sirén, J., Zappalà, A., Jern, P., Bosco, D., Berti, A., & Santtila, P. (2021). Linking serial homicide – towards an ecologically valid application. *Journal of Criminological Research, Policy and Practice*, *7*(1), 18–33.

Pakkanen, T., Zappalà, A., Bosco, D., Berti, A., & Santtila, P. (2015b). Can hard-to-solve one-off homicides be distinguished from serial homicides? Differences in offence behaviours and victim characteristics. *Journal of Criminal Psychology*, *5*(3), 216–232.

Pakkanen, T., Zappalà, A., Grönroos, C., & Santtila, P. (2012). The effects of coding bias on estimates of behavioural similarity in crime linking research of homicides. *Journal of Investigative Psychology and Offender Profiling*, *9*(3), 223–234.

Pallant, J. (2020). *SPSS Survival Manual: A step by step guide to data analysis using IBM SPSS*. Routledge.

Park, Y. S., Konge, L., & Artino, A. R. (2020). The positivism paradigm of research. *Academic Medicine*, *95*(5), 690–694.

Parliament of South Africa. (2025). *Media Statement: DNA backlog exceeding 140 000 cases threatens criminal justice and requires urgent audit by Auditor-General*. Retrieved from: https://www.parliament.gov.za/press-releases/media-statement-dna-backlog-exceeding-

140-000-cases-threatens-criminal-justice-and-requires-urgent-audit-auditor-general. (Accessed 17 July 2025).

Petherick, W. A. (ed.) (2006). *Serial crime: Theoretical and practical issues in behavioral profiling*. Burlington, MA: Academic Press.

Petherick, W. A. (2009). Criminal profiling methods. In W. Petherick (Ed.), *Serial Crime*: *Theoretical and practical issues in behavioral profiling* (2nd ed., pp. 67–108). Burlington, MA: Academic Press.

Petherick, W. A., Bose, S., McKinley, A., & Skrapec, C. (2022). A rose by any other name: Problems in defining and conceptualising serial murder with a new proposed definition. *Journal of Mass Violence Research, 1*(1), 4–24.

Petherick, W. A., & Ferguson, C. (2009). Behavioral consistency, the homology assumption, and the problems of induction. In *Profiling and Serial Crime: Theoretical and Practical Issues* (pp. 37–61). Burlington, MA: Academic Press.

Petherick, W. A., & Turvey, B. E. (2012a). Alternative methods of criminal profiling. In B. Turvey (Ed.), *Criminal Profiling: An Introduction to Behavioral Evidence Analysis* (4th ed., pp. 67–99). San Diego: Elsevier.

Petherick, W. A., & Turvey, B. E. (2012b). Criminal profiling: Science, logic, and cognition. In B. Turvey (Ed.), *Criminal Profiling: An Introduction to Behavioral Evidence Analysis* (4th ed., pp. 41–65). San Diego: Elsevier.

Pistorius, M. (1996). *A psychoanalytical approach to serial killers* (Unpublished PhD thesis). University of Pretoria, Pretoria.

Pistorius, M. (2012). *Strangers on the street: Serial homicide in South Africa*. Johannesburg: Penguin Books.

Pistorius, M. (2018). *Profiling serial killers and other crimes in South Africa*. Cape Town: Penguin Random House South Africa.

Porter, M. D. (2014). A Statistical approach to crime linkage. *American Statistician, 70*(2), 152–165.

Rainbow, L. (2015). A practitioner's perspective. In J. Woodhams & C. Bennell (Eds.), *Crime Linkage: Theory, Research, and Practice* (pp. 173–196). New York: Taylor & Francis Group.

Rainbow, L., Gregory, A., & Alison, L. (2014). Behavioral investigative advice. *Encyclopedia of Criminology and Criminal Justice*, 125–134.

Reale, K. S., Beauregard, E., & Chopin, J. (2022). Criminal expertise and sexual violence: Comparing the crime-commission process involved in sexual burglary and sexual robbery. *Criminal Justice and Behavior*, *49*(1), 98–116.

Reale, K. S., Beauregard, E., Chopin, J., & Wells, N. (2021). Making sense of senseless murders: The who, what, when, and where? *Behavioral Sciences and the Law*, *39*(2), 230–244.

Reale, K., Beauregard, E., & Martineau, M. (2020). Is Investigative awareness a distinctive feature of sexual sadism? *Journal of Interpersonal Violence*, *35*(7–8), 1761–1778.

Ressler, R. K, Burgess, A. W., & Douglas, J. E. (1995). *Sexual Homicide: Patterns and Motives*. New York: Free Press.

Ressler, R. K., Douglas, J. E., Burgess, A. W., Hartman, C. R., & D'agostino, R. B. (1986a). Sexual killers and their victims: Identifying patterns and motives through crime scene analysis. *Journal of Interpersonal Violence*, *1*(3), 288–308.

Ressler, R. K., & Shachtman, T. (1992). *Whoever fights monsters*. London: Simon and Schuster

Ribeiro, R. A. B., & de Matos Soeiro, C. B. B. (2021). Analysing criminal profiling validity: Underlying problems and future directions. *International Journal of Law and Psychiatry*, *74*, 101670.

Roberts, A. R., Zgoba, K. M., & Shahidullah, S. M. (2007). Recidivism among four types of homicide offenders: An exploratory analysis of 336 homicide offenders in New Jersey. *Aggression and Violent Behavior*, *12*(5), 493–507.

Rossmo, D. K. (2019). Geoprofiling serial sexual homicide. In *Routledge International Handbook of Sexual Homicide Studies* (pp. 544–561). London: Routledge.

Rossmo, D. K., & Summers, L. (2015). Routine activity theory in crime investigation. In *The Criminal Act: The Role and Influence of Routine Activity Theory* (pp. 19–32). London: Palgrave Macmillan UK.

Rossouw, Z., & Palys, T. (2025). "Baggage in the business": The investigative challenges of serial homicide. *The Police Journal, 98*(1), 249-268.

Saito, T., & Rehmsmeier, M. (2015). The Precision-Recall plot is more informative than the ROC plot when evaluating binary classifiers on imbalanced datasets. *PLoS one, 10*(3), e0118432.

Salfati, C. G. (2000). The nature of expressiveness and instrumentality in homicide. *Homicide Studies*, *4*(3), 265–293.

Salfati, C. G. (2015). A cross-national comparison of behavioral consistency in serial homicide. In J. Woodhams & C. Bennell (Eds.), *Crime Linkage: Theory, Research, and Practice* (pp. 141–171). New York: Taylor & Francis.

Salfati, C. G. (2019). Consistency of offender behaviors and victim targeting in serial sexual violence: An overview of the field. In W. T. O'Donohue & P. A. Schewe (Eds.), *Handbook of sexual assault and sexual assault prevention* (pp. 781–800). Springer Nature Switzerland AG.

Salfati, C. G. (2021). Investigative psychology. In J. Brown & M. Horvath (Eds.), *The Cambridge Handbook of Forensic Psychology* (pp. 54–68). Cambridge: Cambridge University Press.

Salfati, C. G., & Bateman, A. L. (2005). Serial homicide: An investigation of behavioural consistency. *Journal of Investigative Psychology and Offender Profiling*, *2*(2), 121–144.

Salfati, C. G., Horning, A. M., Sorochinski, M., & Labuschagne, G. N. (2015a). South African serial homicide: Consistency in victim types and crime scene actions across series. *Journal of Investigative Psychology and Offender Profiling*, *12*(1), 83–106.

Salfati, C. G., Labuschagne, G. N., Horning, A. M., Sorochinski, M., & De Wet, J. (2015b). South African serial homicide: Offender and victim demographics and crime scene actions. *Journal of Investigative Psychology and Offender Profiling*, *12*(1), 18–43.

Salfati, C. G., & Sorochinski, M. (2019). MATCH: A new approach for differentiating & linking series of sex worker homicides and sexual assaults. *International Journal of Offender Therapy and Comparative Criminology*, *63*(9), 1794–1824.

Salo, B., Sirén, J., Corander, J., Zappalà, A., Bosco, D., Mokros, A., & Santtila, P. (2013). Using Bayes' theorem in behavioural crime linking of serial homicide. *Legal and Criminological Psychology*, *18*(2), 356–370.

Santtila, P., Pakkanen, T., Zappala, A., Bosco, D., Valkama, M., & Mokros, A. (2008). Behavioural crime linking in serial homicide. *Psychology, Crime and Law*, 14(3), 245–265.

Schlesinger, L., Kassen, M., Blair Mesa, V., & Pinizzotto, A. (2010). Ritual and signature in serial sexual homicide. *The Journal of the American Academy of Psychiatry and the Law*, *38*, 239–246.

Schmuckler, M. A. (2001). What is ecological validity? A dimensional analysis. *Infancy*, *2*(4), 419–436.

Schneider, H. J. (2001). Victimological developments in the world during the past three decades (I): A Study of comparative victimology. *International Journal of Offender Therapy and Comparative Criminology*, *45*(4), 449–468.

Sea, J., Beauregard, E., & Martineau, M. (2019). A cross-cultural comparison of Canadian and Korean sexual homicide. *International Journal of Offender Therapy and Comparative Criminology*, *63*(9), 1538–1556.

Shaikh, S. A. (2011). Measures derived from a 2 x 2 table for an accuracy of a diagnostic test. *Journal of Biometrics and Biostatistics*, *2*(128), 1-4.

Simonini, A., Murugan, J., Vittori, A., Pallotto, R., Bignami, E. G., Calevo, M. G., Piazza, O., & Cascella, M. (2024). Data-driven machine learning models for risk stratification and prediction of emergence delirium in pediatric patients underwent Tonsillectomy/ Adenotonsillectomy. *Annali Italiani Di Chirurgia*, *95*(5), 944–955.

Simons, C. L. (2001). Antisocial personality disorder in serial killers: The thrill of the kill. *The Justice Professional: A Critical Journal of Crime, Law and Society*, *14*(4), 345–356.

Singer, S. D., & Hensley, C. (2004). Applying social learning theory to childhood and adolescent firesetting: Can it lead to serial murder? *International Journal of Offender Therapy and Comparative Criminology*, *48*(4), 461–476.

Skott, S., Beauregard, E., Darjee, R., & Martineau, M. (2021). The consistency of sexual homicide characteristics and typologies across countries: a comparison of Canadian and Scottish sexual homicides. *Journal of Sexual Aggression*, *27*(1), 18–34.

Skrapec, C. A. (2001a). Defining serial murder: A call for a return to the original Lustmörd. *Journal of Police and Criminal Psychology*, *16*(2), 10–24.

Skrapec, C. A. (2001b). Phenomenology and serial murder: Asking different questions. *Homicide Studies*, *5*(1), 46–63.

Slater, C., Woodhams, J., & Hamilton-Giachritsis, C. (2015). Testing the Assumptions of Crime linkage with stranger sex offenses: A more ecologically-valid study. *Journal of Police and Criminal Psychology*, *30*(4), 261–273.

Smillie, S., & Riddell, J. (2023). Supporting emotionally demanding research: Developing guidance for a university research centre. *Qualitative Researcher Vulnerability: Negotiating, Experiencing and Embracing*, 77–93.

Snook, B., Cullen, R. M., Bennell, C., Taylor, P. J., & Gendreau, P. (2008). The criminal profiling illusion: What's behind the smoke and mirrors? *Criminal Justice and Behavior*, *35*(10), 1257–1276.

Snook, B., Cullen, R. M., Mokros, A., & Harbort, S. (2005a). Serial murderers' spatial decisions: Factors that influence crime location choice. *Journal of Investigative Psychology and Offender Profiling*, *2*(3), 147–164.

Snook, B., Eastwood, J., Gendreau, P., Goggin, C., & Cullen, R. M. (2007). Taking stock of criminal profiling: A narrative review and meta-analysis. *Criminal Justice and Behavior*, *34*(4), 437–453.

Snook, B., Taylor, P. J., & Bennell, C. (2004). Geographic profiling: the fast, frugal, and accurate way. *Applied Cognitive Psychology*, *18*(1), 105–121.

Snook, B., Zito, M., Bennell, C., & Taylor, P. J. (2005b). On the complexity and accuracy of geographic profiling strategies. *Journal of Quantitative Criminology*, *21*(1), 1–26.

Sorochinski, M. (2024). Casting light on the unseen victims: A comprehensive review of the ramifications of wrongful convictions and exonerations on families. *International Review of Victimology*, *31*(2), 285-305.

Sorochinski, M., Johnson, M. B., & Gharib, R. (2023). The weakest link? Investigative issues in serial sexual assault that lead to wrongful conviction. *International Journal of Law, Crime and Justice*, *75*, 100632.

Sorochinski, M., & Salfati, C. G. (2010). The consistency of inconsistency in serial homicide: Patterns of behavioural change across series. *Journal of Investigative Psychology and Offender Profiling*, *7*(2), 109–136.

Sorochinski, M., & Salfati, C. G. (2019). Sex worker homicide series: Profiling the crime scene. *International Journal of Offender Therapy and Comparative Criminology*, *63*(9), 1776–1793.

Sorochinski, M., Salfati, C. G., & Labuschagne, G. N. (2015). Classification of planning and violent behaviours in serial homicide: A cross-national comparison between south Africa and the US. *Journal of Investigative Psychology and Offender Profiling*, *12*(1), 69–82.

South African Government. (1988). *Law of Evidence Amendment Act 45* of 1988. Pretoria: Government Printers.

South African Government. (2013). *Protection of Personal Information Act (POPIA) No 4* of 2013. Pretoria: Government Printers.

State v. Nyauza. (2007). Case No CC97/2007. Pretoria High Court, South Africa.

State v. Sukude. (2006). Case No 34/2006. Pietermaritzburg High Court, South Africa.

State v. van Rooyen. (2007). Case No SS 55/2007. Cape High Court, South Africa.

Sturup, J. (2018). Comparing serial homicides to single homicides: A study of prevalence, offender, and offence characteristics in Sweden. *Journal of Investigative Psychology and Offender Profiling*, *15*(2), 75–89.

Sutton, M. R., & Keatley, D. (2021). Cooling-off periods and serial homicide: A case study approach to analysing behaviour between murders. *Forensic Science International: Mind and Law*, *2*, 100066.

Swets, J. A. (1973). The relative operating characteristic in psychology: A technique for isolating effects of response bias finds wide use in the study of perception and cognition. *Science*, *182*(4116), 990–1000.

Swets, J. A. (1988). Measuring the accuracy of diagnostic systems. *Science*, *240*(4857), 1285–1293.

Thongkam, J., Xu, G., & Zhang, Y. (2008). AdaBoost algorithm with random forests for predicting breast cancer survivability. *Proceedings of the International Joint Conference on Neural Networks*, 3062–3069.

Tonkin, M., (2015). Testing the theories underpinning crime linkage. In J. Woodhams & C. Bennell (Eds.), *Crime Linkage: Theory, Research, and Practice* (pp. 107–139). New York: Taylor & Francis Group.

Tonkin, M., Lemeire, J., Santtila, P., & Winter, J. M. (2019). Linking property crime using offender crime scene behaviour: A comparison of methods. *Journal of Investigative Psychology and Offender Profiling*, *16*(2), 75–90.

Tonkin, M., Pakkanen, T., Sirén, J., Bennell, C., Woodhams, J., Burrell, A., Imre, H., Winter, J. M., Lam, E., ten Brinke, G., Webb, M., Labuschagne, G. N., Ashmore-Hills, L., van der kemp, J. J., Lipponen, S., Rainbow, L., Salfati, G. C., & Santtila, P. (2017). Using offender crime scene behavior to link stranger sexual assaults: A comparison of three statistical approaches. *Journal of Criminal Justice*, *50*, 19–28.

Tonkin, M., Santtila, P., & Bull, R. (2012a). The linking of burglary crimes using offender behaviour: Testing research cross-nationally and exploring methodology. *Legal and Criminological Psychology*, *17*(2), 276–293.

Tonkin, M., & Weeks, M. J. (2021). Crime linkage practice in New Zealand. *Journal of Criminological Research, Policy and Practice*, *7*(1), 63–76.

Tonkin, M., & Woodhams, J. (2017). The feasibility of using crime scene behaviour to detect versatile serial offenders: An empirical test of behavioural consistency, distinctiveness, and discrimination accuracy. *Legal and Criminological Psychology*, *22*(1), 99–115.

Tonkin, M., Woodhams, J., Bull, R., & Bond, J. W. (2012b). Behavioural case linkage with solved and unsolved crimes. *Forensic Science International*, *222*(1–3), 146–153.

Tonkin, M., Woodhams, J., Bull, R., Bond, J. W., & Palmer, E. J. (2011). Linking different types of crime using geographical and temporal proximity. *Criminal Justice and Behavior*, *38*(11), 1069–1088.

Tonkin, M., Woodhams, J., Bull, R., Bond, J. W., & Santtila, P. (2012c). A comparison of logistic regression and classification tree analysis for behavioural case linkage. *Journal of Investigative Psychology and Offender Profiling*, *9*(3), 235–258.

Turvey, B. E. (2012a). Inferring offender characteristics. In B. Turvey (Ed.), *Criminal Profiling: An Introduction to Behavioral Evidence Analysis* (4th ed., pp. 403–446). San Diego: Elsevier.

Turvey, B. E. (2012b). Serial cases: Investigating pattern crimes. In B. Turvey (Ed.), *Criminal Profiling: An Introduction to Behavioral Evidence Analysis* (4th ed., pp. 533–568). San Diego: Elsevier.

Turvey, B. E., & Freeman, J. (2012a). Case linkage: Offender modus operandi and signature. In B. Turvey (Ed.), *Criminal Profiling: An Introduction to Behavioral Evidence Analysis* (4th ed., pp. 331–360). San Diego: Elsevier.

Turvey, B. E., & Freeman, J. (2012b). Forensic victimology. In B. Turvey (Ed.), *Criminal Profiling: An Introduction to Behavioral Evidence Analysis* (4th ed., pp. 163–186). San Diego: Elsevier.

Van der Watt, M., Van Graan, J., & Labuschagne, G. N. (2014). Modus operandi, signature and fantasy as distinctive behaviour: Fundamental considerations in the case linkage of child rape cases. *Child Abuse Research in South Africa*, *15*(1), 61–72.

Vincent, J., Williams, D. J., Huff-Corzine, L., & Corzine, J. (2024). Does the number of victims matter in defining serial murder? An analysis of homicide behavioral characteristics in US cases from 1985–2016. *Victims and Offenders*, *19*(4), 641–655.

Walker, G. (2015). The (in)significance of genital injury in rape and sexual assault. *Journal of Forensic and Legal Medicine*, *34*, 173–178.

Walklate, S. (2013). Sexual violence against women. *International Review of Victimology*, *20(*1), 71–84.

Wiest, J. B. (2011). *Creating cultural monsters: Serial murder in America*. New York: Routledge.

Williams, D. J. (2023). Is it time to revisit the definition of serial homicide? New evidence and theory. *Forensic Sciences*, *3*(1), 120–124.

Wilson, C. (2004). *The History of Murder*. New York: Castle Books.

Winter, J. M., Lemeire, J., Meganck, S., Geboers, J., Rossi, G., & Mokros, A. (2013). Comparing the predictive accuracy of case linkage methods in serious sexual assaults. *Journal of Investigative Psychology and Offender Profiling*, *10*(1), 28–56.

Woodhams, J., & Bennell, C. (2015a). Introduction: Time to consolidate and reflect. In J. Woodhams & C. Bennell (Eds.), *Crime Linkage Theory, Research, and Practice* (pp. 1–9). Boca Raton, FL: CRC Press.

Woodhams, J., & Bennell, C. (2015b). Consistency and distinctiveness of criminal behavior. In J. Woodhams & C. Bennell (Eds.), *Crime Linkage: Theory, Research, and Practice* (pp. 11–31). Boca Raton, FL: CRC Press.

Woodhams, J., & Davies, K. (2021). The use of crime linkage in sexual offense cases. *Criminal Investigations of Sexual Offenses: Techniques and Challenges*, 49–63.

Woodhams, J., Hollin, C. R., & Bull, R. (2007). The psychology of linking crimes: A review of the evidence. *Legal and Criminological Psychology*, *12*(2), 233–249.

Woodhams, J., Hollin, C., & Bull, R. (2008). Incorporating context in linking crimes: An exploratory study of situational similarity and if-then contingencies. *Journal of Investigative Psychology and Offender Profiling*, *5*(1–2), 1–23.

Woodhams, J., & Labuschagne, G. N. (2012a). A test of case linkage principles with solved and unsolved serial rapes. *Journal of Police and Criminal Psychology*, 27(1), 85–98.

Woodhams, J., & Labuschagne, G. N. (2012b). South African serial rapists: The offenders, their victims, and their offenses. *Sexual Abuse: Journal of Research and Treatment*, *24(*6), 544–574.

Woodhams, J., Tonkin, M., Burrell, A., Imre, H., Winter, J. M., Lam, E. K. M., Jan ten Brinke, G., Webb, M., Labuschagne, G. N., Bennell, C., Ashmore Hills, L., van der kemp, J., Lipponen, S., Pakkanen, T., Rainbow, L., Salfati, C. G., Santtila, P. (2019). Linking serial sexual offences: Moving towards an ecologically valid test of the principles of crime linkage. *Legal and Criminological Psychology*, *24*(1), 123–140.

Woodhams, J., & Toye, K. (2007). An empirical test of the assumptions of case linkage and offender profiling with serial commercial robberies. *Psychology, Public Policy, and Law*, *13*(1), 59–85.

Wright, J., & Hensley, C. (2003). From animal cruelty to serial murder: Applying the graduation hypothesis. *International Journal of Offender Therapy and Comparative Criminology*, *47*(1), 71–88.

Wright, K. A., Pratt, T. C., & Delisi, M. (2008). Examining offending specialization in a sample of male multiple homicide offenders. *Homicide Studies*, *12*(4), 381–398.

Yaksic, E. (2018). The folly of counting bodies: Using regression to transgress the state of serial murder classification systems. *Aggression and Violent Behavior*, *43*, 26–32.

Yaksic, E. (2022). *Killer Data: Modern Perspectives on Serial Murder*. London: Routledge.

Yaksic, E. (2023). Serial murder. In M. M. Houck (Ed.), *Encyclopedia of Forensic Sciences* (Vol. 4, pp. 451–462). Oxford: Elsevier.

Yaksic, E. (2024). The serial murder phenomenon half a century on. In *Routledge Handbook of Homicide Studies* (pp. 235–269). London: Routledge.

Yaksic, E., Allely, C., De Silva, R., Smith-Inglis, M., Konikoff, D., Ryan, K., Gordon, D., Denisov, E., & Keatley, D. A. (2019). Detecting a decline in serial homicide: Have we banished the devil from the details? *Cogent Social Sciences*, *5*(1), 1678450.

Yaksic, E., Harrison, M., Konikoff, D., Mooney, R., Allely, C., De Silva, R., Matykiewics, B., Inglis, M., Giannangelo, S. J., Daniels, S., & Sarteschi, C. M. (2021). A heuristic study of the similarities and differences in offender characteristics across potential and successful serial sexual homicide offenders. *Behavioral Sciences and the Law*, *39(*4), 428–449.

Yang, M. (2023). What factors shape a serial murderer? *Journal of Education, Humanities and Social Sciences*, *22*, 656–661.

Zappalà, A., Haginoya, S., & Santtila, P. (2022). One and a half centuries of serial homicide in Italy: offender, victim and offence characteristics. *Psychiatry, Psychology, and Law*, *30*(4), 423.

APPENDICES

Appendix A: Turnit-in Plagiarism Report

I have reviewed this Turnitin report and am satisfied that the 'hits' are not indicative of plagiarism, and reflect hits on references, commonly used phrases in the field, names of statistics processes and procedures and organisations, and everyday used phrases.



Prof Gerard Labuschagne: Supervisor

KMcG Turnitin Final 31 March 2025.docx

by Kelly McGivern

KMcG Turnitin Final 31 March 2025.docx

ORIGINALITY REPORT

12%	7%	10%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

Submission date: 31-Mar-2025 01:19PM (UTC+0200)
Submission ID: 2630739935
File name: KMcG_Turnitin_Final_31_March_2025.docx (5.09M)
Word count: 67287
Character count: 369573

Appendix B: WITS HREC (Non-Medical) Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 McGivern

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H20/09/29**
PROJECT TITLE	Behaviour Consistency among Serial Murder Offenders in South Africa
INVESTIGATOR(S)	Miss K McGivern
SCHOOL/DEPARTMENT	Forensic Medicine and Pathology/
DATE CONSIDERED	18 September 2020
DECISION OF THE COMMITTEE	Approved Risk Level: Minimal
EXPIRY DATE	01 November 2023

DATE 02 November 2020 **CHAIRPERSON** J-Knight
(Professor J Knight)

cc: Supervisor : Prof G Laguschagne

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature **Date** 18 / 11 / 2020

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix C: SAPS Permission to Conduct Research

South African Police Service | Suid-Afrikaanse Polisiediens

Privaatsak Pretori3
Private Bag X94 0001

Faks No. (012) 334 3518
Fax No.

Your reference/U verwysing:

My referenceiMy verwysing: **3/34/2**

THEHEAD:RESEARCH
SOUTH AFRICAN POLICE SERVICE
PRETORIA
0001

fnquiries/Navrae: **Lt Col Joubert**
AC Thenga
Tel: **(012) 393 3118**
Email: **JoubertG@saps.gov.za**

APPROVED

Ms KB McGivern
UNIVERSITY OF WITWATERSRAND

RE: PERMISSION TO CONDUCT RESEARCH IN SAPS: BEHAVIOURAL CONSISTENCY AMONG SERIAL MURDER OFFENDERS IN SOUTH AFRICA: UNIVERSITY OF WITWATERSRAND: DOCTORATE DEGREE: RESEARCHER: KB MCGIVERN

The above subject matter refers.

You are hereby granted approval for your research study on the above mentioned topic in terms of National Instruction 1 of 2006.

Further arrangements regarding the research study may be made with the following office:

The Divisional Commissioner: Forensic Services:

- **Contact Person:** Col NM Rababalela
- **Contact Details:** (012) 421 0440/082 378 3457
- **Email Address** : RababalelaM@saps.gov.za

Kindly adhere to paragraph 6 of our attached letter signed on the **2020-09-22** with the same above reference number.

MAJOR GENERAL
THE HEAD:RESEARCH
DR PR VUMA

DATE: 2020 -10- 2 0

Appendix D: Behavioural Checklist (per domain)

Target Selection	Sexual Themes
Victim Murdered	Fully Clothed
Victim Alone	Completely Naked
Female victim	Completely Naked Waist Down
Black victim	Completely Naked Waist up
White victim	Clothing pulled up to expose breasts
Indian victim	Clothing pulled down but still on legs
Coloured victim	Clothing pulled up to expose breasts and clothing pulled down
0-3 years old	Completely Naked but Covered
4-8 years old	Redressed
9-12 years old	Legs Spread
13-17 years old	Underwear on Body
18-64 years old	Underwear at scene off body
65 years and older	Underwear partially on body
South African	Underwear Completely missing
Unemployed	Underwear on body used as weapon
Employed	Penetration Anus
Sex worker	Penetration Vagina
Scholar/school going age	Semen found on victim's body
Pensioner	Injuries to victim's vagina
Employed Other	Injuries to victim's penis
Approach location road/street	Injuries victim's anus
Approach location residence	Semen found in victim's anus
Approach location car	Semen found at crime scene
Approach location victim's work	Foreign object found in victim's anus
Approach location bush/veld	Foreign object found in victim's vagina
Victim known to offender	Foreign object found in victim's mouth
Victim ex-partner of offender	Condom found at crime scene
Victim related to offender (family)	Victim's genitalia mutilated/dismembered
Victim friend/acquaintance/neighbour to offender	Digital Penetration
Victim colleague of offender	

Violence and Control

One offender
More than one offender
Cause of Death (COD) undetermined
COD strangulation
COD ligature strangulation
COD manual strangulation
COD ligature and Manual strangulation
COD sharp object
COD blunt force trauma
COD suffocation/asphyxiation
COD drowning
COD burnt
COD due to multiple injuries
COD neck fracture
Known Sharp object used on victim
Known Blunt object used on victim
Ligature/rope/material used on victim
Firearm presented to victim
Hands of offender used on victim as weapon
Multiple weapons used
Non-lethal assault blunt object
Non-lethal asphyxiation
Non-lethal sharp object
Non-lethal injuries to victim's body
Non-lethal fractures to victim's body
Dismemberment while victim was alive
Hands restrained
Hands restrained behind of body
Hands restrained above head
Victim's feet restrained
Victim's knees restrained
Victim gagged
Victim blindfold
Victim burnt while alive

Crime Scene Dynamics

Body found in Urban area
Body found in open veld/open ground
Body found in building/residence
Body found in body of water
Forced Entry
Forced Entry Door
Forced Entry Window
Room in Disarray
Victim body found on stomach
Victim body found on back
Victim body found on side
Victim body found hanging/suspended
Victim body found in foetal position
Victim body concealed
Only victim's face exposed
Victim upper half of body exposed
Victim lower half of body exposed
Victim fully covered
Only victim's face concealed/covered
Victim found partially covered
Body completely buried
Victim's body dumped from vehicle
Victim killed at body recovery scene
Victim dismembered
Victim head dismembered
Victim's limbs dismembered
Victim's genitals dismembered
No weapon found at scene
Sharp object found at scene
Blunt object found at scene
Ligature found at scene
Victim's body burnt
Victim's body part stolen
Victim's money stolen
Victim's items (jewellery/cellphone) stolen
Victim's clothing stolen