Goal-driven Elaboration of Crime Scripts

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Declaration

I, Hashem Dehghanniri, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the work.

Abstract

This research investigates a crime modelling technique known as crime scripting. Crime scripts are generated by crime analysts to improve the understanding of security incidents, and in particularly, the criminal modus operandi (i.e., how crimes occur) to help identify cost-effective crime prevention measures. This thesis makes four contributions in this area. First, a systematic review of the crime scripting literature that provides a comprehensive and up-to-date understanding of crime scripting practice, and identifies potential issues with current crime scripting methods. Second, a comparative analysis of crime scripts which reveals differences and similarities between the scripts generated by different analysts, and confirms the limitations of intuitive approaches to crime scripting. Third, an experimental study, which shows that the content of crime scripts is influenced by what scripters know about the future use of their scripts. And fourth, a novel crime scripting framework inspired from business process modelling and goal-based modelling techniques. This framework aims to help researchers and practitioners better understand the activities involved in the development of crime scripts, and guide them in the creation of scripts and facilitate the identification of suitable crime prevention measures.

Impact statement

The contributions of this thesis are both practical and theoretical. The findings offer an improvement in our understanding of the crime scripting process and its limitations. This document provides a comprehensive and up-to-date reference for researchers and practitioners who would like to develop, use, or study crime scripts. Some of the limitations of the current crime scripting practices are highlighted that were identified from the literature review. They are also supported by the results of the study that investigated the limitations of scripts that are intuitively generated. A solution to improve the identified problems is also suggested and its feasibility explored through an experiment. Through this, a new structured goal-driven crime-scripting framework is presented that is based on the existing crime scripting literature, goals-based methods, and business process modelling. This novel framework has the potential to help analysts develop better crime scripts, which might then contribute to their effective application, for example, the identification of situational crime prevention measures, policy-making, or requirements identification.

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Chapter 1

Introduction

1.1 Improving the script-theoretic approach

Situational Crime Prevention (SCP) is a criminological approach for reducing crime and security problems. This is principally by uncovering and removing their proximal causes through influencing offender decision-making (Clarke 1997*a*, Newman, Clarke & Shoham 1997). Recognising the importance of this and understanding how offenders commit crime in order to prevent them, Cornish (1994) proposed a script-theoretic approach to model the crime commission processes. Following this approach, analysts represent crime events as step-by-step sequences of actions (referred to as crime scripts) and examine each of those steps to identify the situational factors that can be altered in order to prevent or reduce it.

Since its introduction, crime scripting has observed a growing interest among researchers interested in crime and security (Ekblom & Gill 2016, Leclerc 2017). It

has also been used in various ways such as for crime prevention or risk analysis and from different disciplinary perspectives including criminology, crime science, and computer security (Borrion 2013, Willison 2008) to study various crime types such as robbery, vandalism, and auto theft (Cornish 1994), internal computer fraud (Willison & Siponen 2009), sex offences (Beauregard, Proulx, Rossmo, Leclerc & Allaire 2007, Brayley, Cockbain & Laycock 2011), drug manufacturing and drug dealing (Chiu, Leclerc & Townsley 2011, Jacques & Bernasco 2013), illegal waste activities (Tompson & Chainey 2011), and wildlife poaching (Hill, Johnson & Borrion 2014).

Despite the growing use of the script-theoretic approach, little is known about the process of generating crime scripts and the activities involved in this process. Only a few published studies include details about the development of crime scripts. For examples, Cornish (1994) used a static template called the *universal script* to develop his scripts but he did not describe how the universal script could be used to elaborate scripts. Brayley et al. (2011) and Tompson & Chainey (2011) used bespoke templates for constructing their scripts but the information available about the script development process is very specific to their application. On the whole, a large number of published scripts appear to have been developed using intuitive approaches. Even those that involved a semi-structured method seem to have drawn extensively on the scripter's experience and intuition.

As can be implied from Cornish (1994), a successful application of crime scripting, e.g., assessing a security risk, characterising a modus operandi, identifying crim-

inal requirements, identifying a control measure, etc., requires having a thorough understanding of the problem. This is such that, a poor quality script would provide incomplete or a wrong understanding which might reduce its chance of identifying efficient and cost-effective situational crime prevention measures (Borrion 2013).

It can be argued that unstructured or semi-structured crime scripting methods are unable to lead scripters to generate quality scripts. Indeed, crime scripts that are developed using such methods might have the same shortcomings as other intuitive products (Orloff 2004) such as being incomplete, biased, and built based on wrong assumptions.

Concentrating on this potential methodological issue, this thesis investigates how analysts represent crime commission processes and contributes to the script-theoretic approach by identifying potential areas of improvement. To enhance the quality of crime scripts and provide products more likely to satisfy the end-users, various modifications to the crime scripting process are proposed. Specifically, this work investigates two complementary ideas:

1. Informing scripters about the intended application of their crime scripts before they develop them. This involves considering the purpose for which crime scripts will be used and the goals and requirements of stakeholders of the security problem to address (i.e. the parties who are relevant to the creation and application of the crime scripts).

2. Supporting a more structured crime scripting practice. This consists of de-

veloping a framework that could be easily used by scripters from different fields in their crime scripting task for guiding them in the elaboration and organisation of their scripts.

1.2 Contribution

The research conducted in this PhD work yields four distinct contributions to the field of crime science:

- Chapter 3 is a systematic review of all the articles related to Cornish's *script-theoretic approach* that were published between 1994 and 2016. Firstly, this confirms crime scripting and crime scripts have been growing in popularity, especially in the last decade. Secondly, it shows crime scripts have been used for modelling a large variety of crime and security incidents. Next, it demonstrates the crime scripting approach has been used for a wide range of applications such as crime prevention, policy-making, or risk analysis. Lastly, it synthesises the activities involved in generating a script.

- Chapter 4 presents an experiment designed to test and analyse the similarities and differences between the contents of intuitive crime scripts written by different scripters. The results of this analysis suggest intuitive crime scripts may all contain some information related to the key stages of crime commission process, but, they can be very different in terms of their completeness, which is a key quality criterion of crime scripts.

- Chapter 5 investigates how individual biases might affect the crime scripting process. The results suggest that informing scripters about the intended purpose of their scripts affects what information is selected and used in the crime script. In particular that they are more likely to select information they believe is related to the purpose of their script and consequently ignore other details.

- Chapter 6 presents a novel goal-driven crime scripting framework that can be used by crime analysts and researchers from various disciplines to select and organise the information and content of their scripts. The developed framework provides a simple set of guidelines regarding the crime scripting process and assists scripters in the various crime scripting activities.

1.2.1 Associated publications

To date, three articles have been published from this doctoral research. The first is a *crime scripting process model* (Dehghanniri & Borrion 2016) developed based on data collected for the analyses in this thesis. The second is a *comparative analysis of intuitive crime scripts* (Borrion, Dehghanniri & Li 2017) and the third is *a systematic review of crime scripting* (Dehghanniri & Borrion 2019). In addition, two further manuscripts (based on analyses in this thesis) are currently being reviewed for publication. The first examines *the effects of informing scripters about goals on scripts' content* and the second is *a goal-driven crime scripting framework*. Also, and partially related to the work in this thesis, an article regarding

a multidisciplinary security decision-making framework using crime scripts (Dehghanniri, Letier & Borrion 2015) was published though the core of this paper is not included in this report.

1.3 Structure of the thesis

The remainder of this thesis is organised in six chapters.

Chapter 2 reviews the literature, starting with an introduction to SCP and the script-theoretic approach proposed by Cornish. It continues with a discussion about the quality of crime scripts and includes examples illustrating how higher quality scripts might help identify better crime prevention measures. Following is a critical analysis of crime scripting practices, which highlights a number of potential issues that are relevant to this thesis. The chapter ends with a discussion about the lack of a systematic crime scripting method, the importance of being able to replicate and assess the work of crime scripters, and the possibility that the contents of crime scripts might be dependent upon individual scripters.

Chapter 3 presents a systematic review (SR) conducted to take stock of current crime scripting practices. The work provides useful information about the diffusion of the script-theoretic approach, the types of crimes for which a script is available, the scripting methods applied by researchers, and what 'crime scripts' are called in other fields. This chapter starts with an *introduction* that motivates the SR and the questions that are to be answered in it. Next is the *method* section that details the

process followed to complete the review. Finally is the *results* section that provides the results of the SR and the *discussion* and *conclusion* sections that summarise the main findings.

Chapter 4 tests the hypothesis that the contents of crime scripts depend upon the person or analyst who generated them. This investigation was conducted using experimental data collected from 21 participants who watched a CCTV video of an armed robbery incident and independently wrote a script of the crime commission process. The collected scripts were then compared with each other to understand their similarities and differences. The chapter describes the method applied to collect, code, and compare the 21 crime scripts. The results of the comparison are subsequently presented which confirms there are a number of differences between scripts produced by different scripters.

Chapter 5 examines the possible reasons behind the discrepancy between crime scripts. It discusses possible reasons behind the observed differences and hypothesises that scripters might be influenced by the possible purpose of their crime script. To test this hypothesis, an experiment was conducted that involved asking three groups to script a given crime where each group was provided different information about their intended use of their crime scripts. The chapter provides additional background information about the creation of narratives and, in particular, the information selection in different fields of studies: e.g., social psychology, advertising, health science, and political science. The details of the experiment are then described including how the participants were selected, how they were tasked, how

scripts were generated, and how the collected scripts were coded and analysed. This chapter continues with a descriptive analysis of the collected data and presents the statistical tests used to test the hypotheses. The last sections discuss the main findings of the study, the limitations of the research, and suggest possible directions for future work.

Chapter 6 draws on the results of the previous chapters to develop a framework that could help crime analysts understand how to model crime commission processes and avoid the potential issues that could arise with the intuitive approach. Inspired from the engineering approach, this chapter begins with a brief review of goal-driven techniques from the field of *Requirement Engineering* and *Business Process Modelling*. It then continues by introducing a crime scripting process model that details the successive activities involved in the elaboration of crime scripts. A novel *goal-driven crime scripting framework* is then presented and illustrated using an example. The chapter ends with a summary of the potential benefits and limitations of the framework and an explanation of how it might address the specific issues identified in Chapter 2.

Chapter 7 lists the main limitations of this doctoral research and draws a road-map for future work that could help advance the development and adoption of crime scripting amongst crime analysts and researchers.

Chapter 2

Background

The purpose of this chapter is to introduce crime scripting. It starts with a brief review of situational crime prevention as the origin and motivation behind crime script analysis. It continues with an introduction to Cornish's script-theoretic approach and a review of existing crime scripting techniques. Potential issues with existing crime scripting approaches are also identified.

2.1 Situational crime prevention

There are many approaches to crime reduction. While the majority specifically concentrate on the offenders' propensity to commit crime, situational crime prevention (SCP) operates by altering their judgements of the potential risks and rewards of committing an offence. Specifically, it seeks to deter them from taking certain courses of action by influencing their perceptions of opportunities, typically at or near the time and place of its envisaged commission (Clarke 1997*b*). In relation to

this, twenty-five SCP techniques (see Table 2.1) have been distinguished, such as changing the perceived effort, reward, and excuses associated with the translation of a criminal opportunity into a criminal act (Bullock, Clarke & Tilley 2010). Supported by a body of research, Clarke (2009, p. 3) claimed that these techniques have been successfully applied to a wide variety of crimes including organised crime and terrorism and could be applied across the whole spectrum of crime.

These interventions must however be tailored to the crimes they are meant to address (Goldstein 1979). For this reason, practitioners are encouraged to formulate and analyse problems before settling on a response. To reduce crime risks in public spaces, for instance, problem-solving models recommend crime analysts to collect data that can assist in identifying the crime events likely to occur in such settings. Then model the sequence of activities that form their crime commission processes to determine the situational conditions that permit or facilitate the crime. Next is to settle on the environmental conditions within which offenders are likely to operate and identify factors that influence their decisions to commit certain crimes (Cornish & Clarke 2003).

Table 2.1: Twenty five techniques of situational prevention (Cornish & Clarke 2003)

Increase the Effort	**Increase the Risks**	**Reduce the Rewards**	**Reduce Provocations**	**Remove Excuses**
Target harden: Steering column locks and immobilisers	Extend guardianship: Take routine precautions, e.g., go out in group at night	Conceal targets Off-street parking: Gender-neutral phone directories	Reduce frustrations and stress: Efficient queues and polite service	Set rules: Harassment codes
Control access to facilities: Electronic card access	Assist natural surveillance: Improved street lighting	Remove targets: Removable car radio	Avoid disputes: Fixed cab fares	Post instructions: 'No Parking'
Screen exits: Ticket needed for exit	Reduce anonymity: Taxi driver IDs	Identify property: Vehicle licensing and parts marking	Reduce emotional arousal: Prohibit racial slurs	Alert conscience: Roadside speed display boards
Deflect offenders: Separate bathrooms for women	Utilise place managers: CCTV for double-deck buses	Disrupt markets: License street vendors	Neutralise peer pressure: 'It's OK to say No'	Assist compliance: Easy library check-out
Control tools/ weapons: Disabling stolen cell phones	Strengthen formal surveillance: Red light cameras	Deny benefits: Speed humps	Discourage imitation: Rapid repair of vandalism	Control drugs and alcohol: Breathalysers in pubs

2.2 Crime scripting

Cornish (1994) recognised the importance of taking a crime-specific approach in situational crime prevention and understanding how certain types of crime tend to be committed. He also recommended using a general procedural framework to elicit data about the crime commission process and make sense of them. In his view, the use of a top-down framework would explicitly encourage the investigator to consider the procedural aspects and procedural requirements of the crime-commission process than just 'extracting' a plan from the data themselves. Interrogating the data using a top-down approach and seeking more information than just that suggested by offenders' reports, for example, would allow important omissions, such as missing information about the offence's preparation or aftermath, to be avoided.

Cornish proposed to use a script-theoretic approach as the basis for such a procedural framework. Originating in the book titled 'The Nature of Explanation' (Leddo & Abelson 1986), this approach was initially used to describe accidents though it could be transferred to criminology to support the elicitation of information about crime commission processes, their visualisation as step-by-step narratives, and the identification of *pinch points*— i.e. decision points that could be influenced to disrupt those crimes.

A 'script' in this context 'describes appropriate sequence of events in a particular context'. It is a predetermined, stereotyped sequence of actions that defines a well-known situation (Schank & Abelson 1977, p. 41). Scripts are mental structures that

organise information about a sequence of predictable actions, locations, and roles that constitute events (Bennett 1993). Hewstone (1989) explained that scripts offer a 'concrete explanation about specific actions in specific domains' and Bower, Black & Turner (1979) emphasised that 'script theory is attractive because it separated a fairly well defined, manageable part of cognition'.

Cornish emphasised that script theory could assist in eliciting and analysing offenders' accounts of crime commission. This is because their properties constitute the unique blend of features which distinguish one criminal activity from another in terms of its goals, targets, victims, locations, risks, payoffs, and various complementary offender requirements such as 'motives, expertise, special knowledge, resources, co-offenders, and so on' (Cornish 1994).

Focusing on crime reduction through either generic prevention or disruption of the crime commission process, Cornish (1994) discussed the benefits offered by his proposed procedural framework:

> "[It] provides a useful guide for undertaking systematic studies of attempts and aborted crimes. It may also help to throw light upon the extent to which offenders use standing decisions to enter and abort scripts, or to change direction within scripts (one aspect of displacement) [...] A complete understanding of the crime-commission act and its goals is often necessary before the motivation can be fully understood. The crime-specific approach is therefore a motive-specific one, and proce-

dural analysis can render such motives more clearly" (Cornish 1994).

In the literature, many scholars have shared Cornish's opinion that the script-theoretic approach has a lot to offer to crime analysis. Specifically, various studies have referred to it as a tool for eliciting the offender's behaviour and the rationale for their decisions (Beauregard & Martineau 2015, Beauregard et al. 2007, Chiu et al. 2011, Gamman, Thorpe, Malpass & Liparova 2012, Meijerink 2013, Meyer 2013, Meyer, Jore & Johansen 2015, Willison 2008, Willison & Siponen 2009, Wortley & Mazerolle 2013); whilst others have highlighted its utility in organising existing knowledge about the requirements of crime commission such as the skills or resources that criminals need to deploy in order to execute a crime (Balemba & Beauregard 2013, Basamanowicz 2011, Bichler, Bush & Malm 2013, Cornish 1994, De Vries 2012, 2013, Gilmour 2014, Le 2013, Leontiadis 2014, Meijerink 2013).

2.2.1 Definition of crime scripts

Cornish (1994) explains that the 'script-theoretic approach provides a way of generating, organising, and systematising knowledge about the procedural aspects and procedural requirements of crime commission', and that the result— the crime script— can help identify logical explanations for the occurrence of harm or rule-breaking events.

For illustration, Table 2.2 shows a crime script for auto theft that appears in Cornish's seminal article (Cornish 1994). This script indicates the steps offenders carry

out to 'do the crime', and the same steps can help identify the factors that can be controlled to prevent or disrupt the crime.

Table 2.2: Auto theft crime script (Cornish 1994)

Scene/Function	Steps
PREPARATION	Get screwdriver
	Get scaffold tube
	Select co-offenders
ENTRY	Go to the public car-park
INSTRUMENTAL PRE-CONDITION	Reject alarmed cars
	Choose older Cortina
INSTRUMENTAL INITIATION	Force lock with screwdriver
	Enter vehicle
INSTRUMENTAL ACTUALISATION	Break off trim
	Scaff ignition barrel
	Remove ignition and steering lock
	Activate starter switch
DOING	Drive away and use vehicle
POST-CONDITION	Abandon by next day

There are however diverse views about what crime scripts *are* and *are for*. Many studies have highlighted the capacity of crime scripting to provide a step-by-step description of the actions involved in a crime. Leclerc & Reynald (2015), for example, explained that 'a crime script simply represents the complete sequence of actions adopted before, during, and following the commission of a particular crime'. Chiu et al. (2011) pointed out that 'crime scripts hold this innovative capacity of untangling very complex forms of crime by breaking down the crime commission process into different steps'. Bruns (2015) wrote that 'a crime script is a heuristic device for breaking down a criminal endeavour into functionally, spatially and temporally defined events'. Many other studies mention the capacity of the script-theoretic approach in breaking crime events down into small steps (Brayley et al. 2011, Caneppele & Calderoni 2014, Haelterman 2009, Severns 2015, Tompson & Chainey 2011, Willison & Siponen 2009).

In comparison, Morselli (2009) referred to crime script analysis as a framework for enhancing our understanding of general crime-commission processes. Other studies also described the potential of crime scripts in improving our understanding about the crime processes followed by offenders (e.g., Basamanowicz & Bouchard 2011, Caneppele & Calderoni 2014, Deslauriers-Varin & Beauregard 2010, Hutchings & Holt 2015, Moreto & Clarke 2013, Willison 2005).

Several other studies refer to the value that crime scripting has in organising existing knowledge about the requirements of crime commission such as the skills or resources that criminals need to deploy in order to execute a crime (e.g., Balemba & Beauregard 2013, Basamanowicz 2011, Bichler et al. 2013, Cornish 1994, De Vries 2012, 2013, Gilmour 2014, Le 2013, Leontiadis 2014, Meijerink 2013).

Finally, crime scripts, as described by Choi, Lee & Chun (2015), provide 'different insights on the decision making and behavioural pattern in each step of the commission of a crime'. The 'offender's behaviour' and the 'rationale for their decisions' are found in the definitions available in Beauregard & Martineau (2015), Beauregard et al. (2007), Chiu et al. (2011), Gamman et al. (2012), Meijerink (2013), Meyer (2013), Meyer et al. (2015), Willison (2008), Willison & Siponen (2009), Wortley & Mazerolle (2013).

2.2.2 Quality of crime scripts

Borrion (2013) listed twelve criteria that can be used to assess the quality of crime scripts: typology, traceability, transparency, consistency, context, completeness, parsimony, precision, uncertainty, usability, ambiguity, and accuracy. Three of them are reviewed in the following sections to illustrate how improving the quality of crime scripts can support analysts in the identification of pinch points and interventions, and ultimately in reducing crime. Particularly relevant to this thesis, these three criteria are completeness, parsimony, and traceability.

Completeness

Completeness is one of the main characteristics of any model. Borrion (2013) indicated that crime scripts should include as much relevant information about the elements that significantly influence the likelihood and consequences of a crime as possible. Completeness is a concern in different disciplines. Yue (1987) examined the completeness of the specifications of software systems, based on the goals they are expected to satisfy. Considering that the requirements concerning the development of a system are logically derived from the goals of those who commission or use it (i.e. what they want or expect from it), 'goals' can therefore be used as a basis for assessing the completeness of the requirements. Yue suggested that requirements are complete if they are sufficient to establish the goals they are derived from.

Table 2.3 represents a script written by Willison (2006*a*), describing a computer

abuse and proposed several interventions to mitigate the identified risk. Like many others, this script focuses on the activities conducted by the offender.

Table 2.3: Computer abuse script (Willison 2006*a*)

No	Crime script function	Intervention
1	Deliberately gaining access to the organisation	Screening of prospective employees
2	Already authorised as employee	-
3	Wait for employees absence from offices	Physical segregation of duties Staggered breaks Signing in/out of offices
4	Access to colleagues' computers	System time outs Biometric fingerprint authentication
5	Access programmes	Password use for access to specific programmes
6	False customer account construction	Two-person sign-off on new accounts
7	Authorisation of fictitious invoices	Audit of computer logs Budget monitoring
8	Exit the application	-
9	Exit the system	User event viewer

However, it can be argued that none of the single interventions proposed in this table can mitigate the identified risk to an acceptable level. Table 2.4 describes the interventions that were shown in Table 2.3, and shows their correspondent prevention techniques, among the techniques that are presented in Table 2.1.

A new intervention is suggested in Table 2.5 that could help reduce the risk to the organisation. The table is an updated version of the script shown in Table 2.3 but includes one extra step: 'Invoice confirmation'. This step has not been derived directly from the activities of the offender but comes from the perspective of other stakeholders (e.g., a security consultant). Considering this new step, it is proposed to enforce a multiple confirmation and announcement when a new invoice is issued. That is, immediately after requesting a new invoice, confirmation requests are sent to the issuer and their manager account, and announcement emails are sent to both the issuer and their manager. To commit the crime successfully, the offenders must

Table 2.4: Computer abuse script— Intervention impact

Intervention	Countermeasure	Relevant SCP technique
Screening of prospective employees	Conducting background checks before hiring employees; to mitigate risk of frauds.	Reduce provocation; reduce emotional arousal
Physical segregation of duties	Having separate office for employees who have access to critical resources/software; to reduce the possibility of unauthorised access to critical software applications.	Increase the effort; deflect offenders
		Reduce provocation; avoid disputes
Staggered breaks	Asking employees not to go for break (or arrive and leave) at the same time to improve the periods of overlap, which decrease this possibility that the offender be in the office alone.	Increase the risks; use place managers
System times out	Auto log-out if system is not being used for a certain amount of time, that decrease the chance of unauthorised access to the others systems	Reduce the reward; remove target
		Increase effort; controlling access
Biometric fingerprint authentication	Improving authentication that makes password hacking/unauthorised logging harder	Increase effort; controlling access
Password use for access to specific programmes	Authorisation; extra checks to reduce the chance of unauthorised access to a critical software, even though the offender has already access the system	Increase effort; controlling access
		Increase effort; control use
Signing in/out of office	For monitoring presence of employees, can be used for accountability purposes	Remove excuse; assist compliance
		Reduce rewards, deny benefits
Audit of computer logs	For monitoring accesses to the resources and users activity, for accountability purposes	Remove excuse; assist compliance
		Reduce rewards; deny benefits
Budget monitoring	For knowing where money has come from and where that is spent for, for accountability purposes	Remove excuse; assist compliance
		Reduce rewards; deny benefits
User event viewer	For monitoring accesses to the resources and users activity, for accountability purposes	Remove excuse; assist compliance
		Reduce rewards; deny benefits
Two-person sign-off on new accounts	For monitoring users access to accesses to the resources and users activity, for accountability purposes	Increase the effort, target harden

therefore remove the traces of the newly published invoice from the four places (issuers and their manager accounts and emails) which is unlikely to be easy for the offender. It is also likely that employees would probably perceive this intervention favourably compared to, for example, installing in office CCTV or checking users' log activities. It can be argued that enforcing multiple confirmation and announcement of a critical activity would be more reliable/trustable than self-confirmation or other proposed interventions.

Table 2.5: Computer abuse script based on (Willison 2006*a*) with one additional step

No	Crime script function	Intervention
1	Deliberately gaining access to the organisation	Screening of prospective employees
2	Already authorised as employee	-
3	Wait for employees absence from offices	Physical segregation of duties Staggered breaks Signing in/out of offices
4	Access to colleagues' computers	System time outs Biometric fingerprint authentication
5	Access programmes	Password use for access to specific programmes
6	False customer account construction	Two person sign-off on new accounts
7	Authorisation of fictitious invoices	Audit of computer logs Budget monitoring
8	Exit the application	-
8.1	Invoice confirmation	Confirmation requests for newly issued invoices are sent to the issuers and their manager's accounts; announcement messages are also emailed to them. Confirmation request should be sent immediately, but confirmation should be done at least one working day after the request was sent.
9	Exit the system	User event viewer

Parsimony

Parsimony is another quality for crime scripts. As explained by Borrion (2013), crime scripts 'should not include any information about those elements that are not relevant to the stakeholders' high-level requirements'. Indeed, a model with a lot of information is not necessarily a good model if the information is considered irrelevant to the problem for which the script was created. Effectively, too much information can make the model unnecessarily complicated. In his book titled *Reconstructing the past: Parsimony, evolution, and inference*, Sober (1991) wrote that 'the best explanation of the [information] is the one that minimises a particular quantity'. Therefore, a crime script that is not parsimonious would negatively affect any crime analysis process.

As an example, let us consider that the main purpose of generating the crime script in Table 2.3 is to prevent (rather than detect) computer abuse crime incidents. Arguably, it could be said that step 8 ('Exit the application') is perhaps not relevant to the goal of crime prevention since this step was not considered as a pinch point, and no intervention was proposed based on it. This step also does not seem to improve the readability of the script as step 9 ('Exit the system') has the required exit actions. Moreover, usually exiting a computer system (e.g., shutting down/logging out) involves exiting the open applications too. In short, it seems that this step neither contributes to identifying prevention measures, nor to readability of script. This implies removing the step causes no harm to scripting purpose. It can be argued that keeping/having this step would make the script more complicated and needs extra time for analysis.

Traceability

Traceability refers to the connection between the information contained in a crime script and the objectives of the problem (e.g., designing a measure that can deter potential offenders) (Borrion 2013). In the context of requirements specification (RS), Gotel & Finkelstein (1994) define traceability as 'the ability to describe and follow the life of a piece of information requirements in both forward and backward directions, from its origin to its specification, its subsequent deployment, use, and development, and through all periods of on-going refinement and iteration in any of these phases'. As described in IEEE (1984), traceable information (i.e. requirement in this case) has a clear origin, which can assist the process of assessment of that

information (e.g., its correctness). Gotel & Finkelstein (1994) considered two types of traceability: *Pre-RS* and *Post-RS*, which refers to *before* and *after* specifying the information in a requirement's life, respectively.

As an example, let us consider the sixth step of the auto theft crime script represented in Table 2.2: 'Choose older Cortina'. Although this script is not just about a specific car make (Cortina), assuming crime prevention as the main goal, it is not clear how this step is related to the goal. Does it point to a particularly prevalent type of target? Does the step help understand why the offence was possible or likely? Alternatively, does it help security consultants design suitable interventions? These questions can be asked to assess whether there is any connection between the information that features in this step and the goal(s) of the crime scripting process.

2.2.3 Elaboration of crime scripts

This section reviews different crime scripting methods, discusses their benefits and limitations, and presents a set of principles and procedures for selecting and organising the content of scripts. It starts by reviewing the scripting approaches used in Cornish's 1994 original article (i.e. the *universal scripts* and the *script permutator*). It then discusses scripting methods found in later works (e.g., the *template* and *intuitive* methods).

Cornish (1994) suggested two means for generating, organising, and systemising knowledge about the procedural aspects and procedural requirements of crime com-

mission:

1. 'By providing a way of eliciting offenders' subjective accounts of crime commission (i.e. offender-based offence scripts)', and

2. 'By providing a framework for constructing more comprehensive and objective accounts of crime commission synthesised from offenders accounts and other sources of information'.

Cornish (1994) has many scripts, which were developed using a statistic template that is known as the *universal script*. Despite its limitations (see below) this template has been used by many scripters to develop their scripts.

The universal script

Inspired by Schank (1983), Leddo & Abelson (1986) suggested that scripts can be 'abstracted into a set of generalized scenes' and 'each of which summarizes some basic actions that can be executed in a range of possible manners and contexts'. Scenes are similar in function regardless of the script they come from. For example, Schank & Abelson (1977) described a restaurant script written from the customers' point of view that describes the process they would follow when going to a restaurant. This script includes four scenes: entering, ordering, eating, and exiting.

Cornish (1994) adopted this idea for the development of crime scripts and proposed to rely on a generic template— the 'universal script'— to describe the various elements of a crime commission process. As illustrated in Table 2.2 (page 29), 'such

universal scripts consist of scenes arranged in a sequential order which further the overall actions, offer standardised guidelines for constructing scripts at the *track-level*, whatever the state of knowledge about the offence in question' (Cornish 1994, p. 10).

A script can also have different variants or tracks. For example, the restaurant script could be further specified to create a *fast-food track* or a *coffee-shop track*. These tracks would share the same schema representing the knowledge common to all variants but also have a number of unique slots. For example, a schema for a computer will have the common structure (i.e. display, keyboard, mouse, etc.) but slots will be different based on the exact computer (e.g., colour, processing power, screen size, keyboard's language, etc.) (Schank & Abelson 1977).

Although the universal script suggested by Cornish is relatively easy to understand and use, it is a static template that arguably cannot be effectively re-used to model all types of crime. The main problem here is that not all the types of crime have the same types of scenes; for example, internal-computer-abuse crime (Willison 2006*a*) has a very different list of functions and scenes compared to car-jacking that was modelled [using the universal script] in Cornish (1994). Therefore, there is a need for a different template to the universal script to elaborate computer abuse crime script steps.

The template approach

Reflecting on the limitations of the universal script, Cornish (1994) discussed 'the script permutator' as a more dynamic method for elaborating scripts. This is a simple three-dimensional model of a typical crime-commission script that can be used as a model for defining new scripts. Other works such as Cornish & Clarke (2008) proposed a more detailed method. For this, they used a newly designed template that outlines the necessary crime scenes and functions involved during a crime commission (e.g., preparation, entry, doing, and exit). They highlighted that 'crime scripts are designed to help identify every stage of the crime commission process, the decision and actions that must be taken at each stage, and the resources (such as criminal cast, props, and suitable locations) required for effective actions at each step'. The current report refers to this method the *template method*, which is a dynamic version of the universal script.

To represent the crime-specific process, the template approach follows the idea of the universal script: first, a set of generalised scenes are identified. After, the scenes are populated with specific actors and actions. The generated scripts range from comparatively simple sequences of actions to more complex models which can include several participants, locations, and actions. In fact, more complex models can result in the emergence of multiple crime scripts. This raises the question of *which script should be selected*.

The template approach has been used in many other studies including Basamanow-

icz & Bouchard (2011), Beauregard et al. (2007), Dehghanniri et al. (2015), Hiropoulos, Freilich, Chermak & Newman (2013), Lavorgna (2014*a*), Leclerc & Reynald (2015), Leukfeldt (2014), Samonas (2013), Tompson & Chainey (2011), and Willison & Siponen (2009), implicitly.

Amongst them, Tompson & Chainey (2011) adopted a template-based method to model illegal waste crime processes. They then used the resulting crime scripts to understand what data was required to help the investigation, detection, and prevention of illegal waste activities (see Figure 2.1).

CREATION	STORAGE	COLLECTION	TRANSPORT	TREATMENT	DISPOSAL
Scene:	Scene:	Scene:	Scene:	Scene:	Scene:
Cast:	Cast:	Cast:	Cast:	Cast:	Cast:
Activities:	Activities:	Activities:	Activities:	Activities:	Activities:

Figure 2.1: The template used by Tompson & Chainey (2011) for constructing their crime script

Example: As an example of template approach to crime scripting let us review the method that was developed and used by Tompson & Chainey (2011); which can be described in the following four-step process:

- Breaking the event down into acts: the authors elicited the main stages (acts) involved in the crime commission process from the literature. In the specific case of illegal waste activities, those were creation, storage, collection, transport, treatment and disposal.

- Writing the script: the authors characterised each act with information about the cast (participants or actors) and the activities involved alongside other

information about potential opportunities for committing the crime.

In this part of the process, analysts identify key information gaps and the types of information that would be useful to collect such as particular facts or evidence that may be required to support an investigation into the suspected offence. In the study by Tompson & Chainey (2011), the process of seeking information shaped the existing structured crime scripting methods. That is, based on the evidence observed in the specific activities (e.g., 'where the waste is being transported').

The aforementioned process consists of four generic scenes: preparation, pre-activity, activity, and post-activity.

- Interpreting the content of the script and visualisation: after collecting the information, the authors attempted to make sense of the collected information by visualisation, interpretation, and analysis.

- Identifying how to tackle the problem: the script that was developed provided a structure for the data, allowed the authors to gain insight in the problem and was used as a tool to analyse the process of that problem.

The template method is arguably the most structured approach to crime scripting. However, studies suggest that every step in the designed templates (including the universal script) is applicable to any given crime type and none of the designed templates is generic enough for modelling all types of crime.

Figure 2.2 shows a crime script developed in Tompson & Chainey (2011).

Scene classifications and their corresponding activities. Names are entirely fictional, and are only included for illustration

Tyres being COLLECTED by an offender		
Scene classification	Cast	Corresponding activities
Preparation	Offender – rogue waste tyre collector: Mr A (leading actor)	Offender is aware that independent garages need to maximise profits and identifies an opportunity to undercut legitimate tyre collectors.
Pre-activity	Offender: Mr A (leading actor) Independent garage owner: Mr B, Shireville Garage (supporting cast member)	Offender approaches owner of independent garage (useful data to collect/record by practitioner: address, date, time of day, size of garage) and explains he can reduce their current tyre removal costs. He produces fraudulent paperwork that purports him to have an appropriate environmental license. The owner of the independent garage agrees to the transaction.
Activity	Offender: Mr A (leading actor)	The tyres are loaded into the offender's vehicle.
Post-activity	Offender: Mr A (leading actor)	The offender takes with him the fraudulent environmental license so that the garage owner cannot verify its legitimacy.

Figure 2.2: Populating scenes in Tompson & Chainey (2011)'s template

The template proposed by Cornish & Clarke (2008) was not directly applicable to the above study about waste crime. In the first case, the scripts included ten scenes (*preparation*, *enter setting*, *pre-condition*, *target selection*, *initiation*, *continuation*, *completion*, *finish up*, *post-condition*, and *exit setting*). In comparison, in the second, it was only comprised of six activities (*creation*, *storage*, *collection*, *transport*, *treatment*, and *disposal*) which are then populated based on four scenes: *preparation*, *pre-activity*, *activity*, and *post-activity*. Only one scene is however shared between them.

The template used by Cornish & Clarke (2008) may be suitable for modelling burglary or other similar types of crime but may not be best suited for modelling all

types of crime, including *waste crime* (Tompson & Chainey 2011) or *human trafficking* (Brayley et al. 2011). To construct a crime script using the template method, it is often the case that scripters will need to (or prefer to) develop a bespoke template specifically adopted to their crime of interest and populate it with details about the various steps of the crime commission process.

In the following, I examine how templates have been developed. Brayley et al. (2011), Cornish & Clarke (2008), and Tompson & Chainey (2011), for example, have all used templates and provided some details. From this information, it appears they have applied very different methods to create them: e.g., for identifying scenes and populating them. It seems their templates were developed using their intuition and based on their experience, knowledge, and application.

Therefore, the template methods arguably have the same shortcomings as any other intuitive method: they can be incomplete, biased, and built based on wrong assumption; and these points are discussed later in this section. Furthermore, designing a generic template that covers all possible of crime, if possible, would be extremely complicated and would result in an overly sophisticated and difficult to use model.

Intuitive method

As explained in the previous sections, there is no well-established crime scripting practice and most crime scripters rely on their intuition, at least to some extent, for the development of crime scripts.

By definition, modelling crime using an intuitive method is based on people's intuition and therefore involves, to some extent, acquiring knowledge without proof, evidence, or conscious reasoning, or without understanding how the knowledge is acquired (Orloff 2004). As a result, the contents of the crime scripts generated using an intuitive approach is likely to vary between scripters, and depend upon their cognitive abilities, experience, knowledge, and interest (note: this hypothesis is tested in chapter 4).

That being said, there are benefits of using intuition in the production of robust crime scripts. For example, i) the amount of resources (e.g., time, tools, and data sources) required for developing scripts is likely smaller for intuitive approaches, ii) using intuition may also allow more space and flexibility for the creativity of the scripters; they can freely follow their instincts and do what "feels right", iii) structured methods have been developed using their designers' intuition, and iv) no matter how structured a crime scripting method is, scripters are still required to use intuition in completing specific tasks e.g., choosing data-source or visualisation (Orloff 2004, Tesser & Collins 1988, Tyre, Eppinger & Csizinszky 1993).

Despite these benefits, the quality of the resulting unstructured intuitive scripts is questionable. This point is based on the findings of a study comparing systematic and intuitive problem-solving methods in another domain:

> "According to psychologists, most people are poor intuitive problem solvers. They tend to adopt a definition of a problem without having

> collected descriptive data on the situation. They formulate [explanations] based upon incomplete data, and fail to seek out possible alternative explanations. Even when information is available, it is often ignored if it does not support existing preferences and assumptions" (Tyre et al. 1993).

Based on this, it can be hypothesised that scripts that are generated intuitively (or mostly intuitively) are likely of lower quality than those generated using a (more) structured method. Also, that the quality of intuitive scripts' depend on the scripters' abilities in relation to the script's applications. It is possible that such scripts have lower levels of completeness, which might limit the ability of crime analysts to identify cost-effective interventions, or that they have a lower level of parsimony, which might make crime analysis more difficult to use. If scripters are oblivious to or confused about the purpose of scripting, they are potentially prone to making wrong assumptions and will therefore create their scripts based on those wrong understandings and assumptions. This implies that their content might be very different from what it should be. Similarly, such scripts cannot be relied upon for identification of cost-effective and efficient situational crime prevention measures.

The other scripting methods

Prior to Cornish's original article in 1994, 'free form techniques borrowed from cognitive psychology' were initially used for eliciting people's knowledge of routine activities (Bower et al. 1979). Later studies then started employing more system-

atic and structured approaches. These approaches were, however, mostly custom to the each study because they were developed for their specific analysis. For example Brayley et al. (2011) mentioned there is 'no set script creation rules'. For this reason, they developed and used their own scripting method and typology of symbols for the generation of their crime script. In this process, they identified three key stages of *internal child sex trafficking* (i.e. *find*, *groom*, and *abuse*), which they populated with *variations* of relevant actions.

In addition to the universal script, the permutator and the template methods presented in the previous sections, there are two other key ideas that are worth introducing:

Multi-dimensional script development: considering various ways to complete a stage in a crime process, multi-dimensional perspective was adopted in several studies. Ekblom & Tilley (2000), for instance, recommended not to approach crime scripting as a linear process but instead to look at possible alternation of crime-commission process. In line with this advice, Morselli & Roy (2008) created multiple [ringing] crime scripts considering possible variations of each step. Their work discusses the actors who must be involved in the execution of each crime scene for the crime to succeed, and populated the identified scenes by the actors' relevant actions.

Opportunity perspective method: Jacques & Bernasco (2013) used rational choice and opportunity perspective to generate their script. As explained in their study, the

concept of an 'opportunity structure' helps in identifying the necessary conditions for offences. Rational choice perspective— as 'a comrade of opportunity perspective'— is used to analyse criminal's behaviour. It has three main features. First, it assumes criminal behaviour is goal-oriented, second, it focuses on offence-specific analyses, and third it involves distinguishing between criminal involvement (the process of criminal initiation, continuance, and distances) and criminal events (the process of choice that relates to immediate circumstances and situations) (Clarke & Cornish 1985).

Although the above studies provide some tips and examples for crime scripting practices, similar to the template and intuitive methods, they still have their own limitations. First, these methods have been developed based on their authors' intuition. They therefore inherit the same limitations as any intuitive method (see earlier). Second, it has not been explained how these methods have been developed and so verifying them is not practical. Third, and last, it is hard and not cost-effective to replicate them because they are too specific to a certain type of crime and they have largely not been detailed enough to be replicated or reused.

2.3 Gap

At this stage of the thesis, it is worth summarising the main points of this chapter. From the literature, it appears that there is no widely recognised method for modelling crime commission processes. This implies that crime scripting is, at least to some extent, an intuitive process. Even if some scripters have used templates

for elaborating crime scripts (e.g., Tompson & Chainey 2011, Brayley et al. 2011), those templates have been developed in an intuitive way.

This reliance on intuition is potentially problematic for several reasons:

- The crime scripting process may not be intuitive to everyone and the script development task may not have the same meaning for everyone. Different people will have individual characteristics such as their experience (e.g., in crime scripting, SCP measure identification, crime modelling, attack scenario, etc.), knowledge, cognitive abilities, personal interests and biases, and so forth. All these personal factors can affect the quality of their scripts if they are created intuitively. This implies that scripts generated by different scripters, relying on same data, could have varying levels of quality and different contents. If it is confirmed that using current (intuitive or semi-intuitive) crime scripting methods, a replicable result is not guaranteed for each and every script, this could be an issue for those who rely on the scripts to identify prevention measures. Indeed, it would not be certain that the scripts generated by different analysts may lead to different numbers of interventions, for example.

- Intuitive crime scripting approaches probably inherit many of the shortcomings of other intuitive methods. Intuitive approaches are too dependent to the people's personal qualities e.g., their experience, knowledge, interest, age, language, mood, cognitive skills, time, bias, etc. Therefore they are likely to be incomplete, biased, and built based on wrong assumptions. These are real

threats to the quality of the intuitive product. As such, and while they may be easier to make and these limitations may be acceptable in some usage, they are not verifiable.

- The lack of a systematic and structured method means it might not be easy to assess the validity of the resulting scripts. A key factor in the validation of a product is the knowledge about its development process. If a product is developed using a systematic method and all its development activities are documented, the process can be replicated to assess whether same product can be reproduced. The details of the process can also be reviewed and assessed in terms of its correctness and other required criteria. An intuitive product relies on nothing but its creator's intuition and so there would be no documentation or explanation behind its development and therefore it would not be possible to assess this process as a whole, or to verify the activities involved in the process, or even reproduce the product. As such, evaluating the product can be impossible and even if an intuitive product is acceptable by its user, it adds no value to intuitive method as that product cannot be reproduced.

Apart from intuitive scripting approaches, some other semi-intuitive scripting methods (i.e. the universal script, the script permutator, and the template approach) have also been used in the literature. These however also inherit the limitations of intuitive methods. That is, and while intuitive methods are generic and can easily be deployed by other [new] scripters, they may not be re-usable because they are specific to a precise crime problem or environment. They therefore cannot be di-

rectly re-used and must be adapted for other crime prevention studies (where the investigated crime phenomenon or the environment may be different).

Some other problems exist in the current scripting approaches that negatively affect their final product. These include:

- Focusing on single goal: when scripting methods are placed into context, and the goal of the script-to-be is indicated, they tend to focus on the same goal, e.g., crime reduction. Crime reduction is often presented as the main goal of situational crime prevention studies (Goldstein 1979, Newman et al. 1997). However, there should be other stakeholders' goals e.g., to ensure that the side-effects are acceptable (Ekblom & Tilley 2000). This is because focusing too much on a single general goal can result in ignoring a wide range of other goals that are of concern to different parties that affect or are affected by a security product.

- Offering little help in identifying relevant information for scripts: many studies have deployed script analysis and a large number of them have published their used scripts. However, finding a guideline to identify the scripts' content is still challenging. Cornish & Clarke (2008) presented some general guidance about generating crime scripts and listed some types of the information that should be in scripts, but they did not describe how to identify this information. For example, a suburban burglary script that was shown in their work contains 'drive into development' as the only action in the 'enter set-

ting' scene, yet, it has not been clarified how this action was elicited or why no alternative for that action was mentioned.

Other studies (e.g., Cornish 1994, Tompson & Chainey 2011) provided some generic guidance and general points about the information that should be in scripts (e.g., the requirements for the crime to occur, the offender decision-making process, or the actions involved in the crime process). However, none explained where those requirements and actions originate from and how they are related to the application of crime script. There was no explanation about how to identify the required information for a crime script of a specific crime type. In short, the reviewed studies have not stated the origin of the elicited steps (or scenes), the logic behind the selection of the steps, and justification of their selection.

One possible reason for the above problems is that the existing methods are not structured, nor are they systematic or provide guidance to the scripters on how to develop crime scripts. Therefore, it can be argued that not only would a more structured method help scripters in elaborating crime scripts, but it would also assist them in evaluating the quality of their products.

The need for having a more structured crime scripting approach is supported by Orloff (2004) and Polya (1945) who suggest the use of explicit, usable, and clear structured methods to improve the shortcomings of intuitive methods. Moreover, Tompson & Chainey (2011) also advised 'for the purpose of greater practical utility [crime scripting process needs] to be streamlined', which can be accomplished by

developing a structured crime script elaboration approach.

Furthermore, following the instructions of a structured crime scripting method might make the process of generating crime scripts easier, faster, and more replicable.

2.4 Research objective

The overall aim of this research is to analyse existing crime scripting processes and suggest possible improvements that could help generate higher quality scripts. To achieve this aim, four interlinked research objectives were pursued that emerged from this literature review:

- Chapter 3: conduct a systematic review of studies directly related to 'crime scripting' that covers multiple aims i.e. to examine the popularity and potential market of crime scripting. The goal of this is to verify the motivation of this PhD research and to better understand the crime scripting literature. For example, to investigate how prevalent the intuitive approach to crime scripting is, and synthesise information about the methods adopted to script crime. The result of this chapter and chapter 4 would confirm whether there exists any need to improve crime scripting practices.

- Chapter 4: conduct an experiment to ascertain the extent to which the contents of crime scripts depends upon their creators. The results of this study are instrumental in justifying this doctoral work, as the presence of differences be-

tween the scripts generated by different scripters (about the same crime event) provides evidence against the current intuitive approach to crime scripting.

- Chapter 5: conduct an experiment to examine whether the content of a crime script depends on the scripter's understanding of the purpose of the script. The experiment will demonstrate the need to develop a new framework that explicitly integrates the goal(s) of the crime scripting process into the crime scripting process itself.

- Chapter 6: propose a more structured crime scripting framework that outlines the activities involved in the elaboration of high-quality crime scripts and contributes to addressing the issues identified in chapters 4 and 5.

Chapter 3

Crime scripting— a systematic review

3.1 Introduction

As explained in the previous chapter, this research aims to support the identification of crime reduction measures by empowering analysts to develop 'better' crime scripts. For this, it is essential to have a comprehensive understanding of crime scripting, its popularity as a crime modelling technique, its potential in modelling different types of crimes and existing approaches, as well as alternative modelling techniques. Understanding those aspects requires an extensive and up-to-date knowledge of the literature and so in this chapter a systematic review of the crime scripting literature is conducted.

Systematic reviews provide one of the most reliable sources of research evidence.

They aim to collect all available secondary data from previous studies, to filter and analyse that data, and to synthesise the findings either qualitatively or quantitatively (Buchwald, Avidor, Braunwald, Jensen, Pories, Fahrbach & Schoelles 2004, Gough, Oliver & Thomas 2012).

This chapter starts by the *background* section that introduces the motivation of this research and describes its objectives. It continues by the *method* section that details the undertaken method to conducting the review including formulating objectives, search strategy, selection rules, and data extraction. Next is the *results* section that summarises the findings and answers the research questions of this systematic review. Then comes the *discussion* section that describes and analyses the gained results. Finally, the chapter ends with a *conclusion* section that briefs what are learnt from the results of this systematic review.

3.2 Background

As with many techniques, crime scripting has developed rather organically, with limited top-down guidance or coordination between researchers. Based on more than two decades of research (from the publication of Cornish's seminal article), the first objective of this systematic review is to test the claim that the script-theoretic approach has been increasingly in popularity in recent years (see Ekblom & Gill 2016, Leclerc 2013, 2017). If confirmed, this trend would be an indicator for one or both of two reasons: it might imply that more empirical examples are now available to demonstrate the value of this approach as a potential crime reduction tool, and/or

it might reflect an expansion of the crime script community, and therefore encourage others to learn and apply this approach.

The second objective of this study is to compile a list of references that crime analysts could consult to find scripts. As time goes by, it is becoming increasingly difficult to keep track of what types of crime have been scripted and hence to identify related gaps in the literature. Although illustrative lists can be found in the literature (e.g., Borrion 2013, Leclerc 2013), none represents an exhaustive resource. As a result, certain crime scripts may not be used— for example, if analysts are unaware of their existence— and knowledge gaps are still difficult to identify. By compiling the first comprehensive catalogue of relevant publications, it is hoped that this work enhances the impact of published research and stimulates further progress in this field.

The third objective of this review is to take stock of crime scripting methodology. Whilst there is no unique scripting method (Brayley et al. 2011), little is known about the diversity of methods used. For this reason, I decided to examine how researchers identify relevant data sources, select visualisation models, and assess the scripts they generate. Carefully analysed, this information can be used to create guidelines for crime reduction practitioners, identify methodological issues, and support the development of high-quality crime scripts.

The fourth objective was to identify synonyms of the term ‘crime script’ and related works. In engineering, for example, similar concepts— use cases and busi-

ness process models— have been used for several decades to represent how socio-technological systems work and how users interact within them (Claus, Ehrig & Rozenberg 1979, Navare 2003). Identifying those will help raise awareness about the knowledge, models, techniques, and tools that could be borrowed from other fields to improve the quality of crime scripts.

3.3 Method

3.3.1 Overall approach

To take stock of crime scripting practices, I have conducted a systematic review of relevant studies published between 1st January 1994 and 31st December 2016. Systematic reviews are commonly used in the field of crime prevention (e.g., Bowers, Johnson, Guerette, Summers & Poynton 2011, Sidebottom, Tompson, Thornton, Bullock, Tilley, Bowers & Johnson 2015, Snook, Eastwood, Gendreau, Goggin & Cullen 2007) and are generally considered well suited to produce up-to-date summaries of studies in an area and give an objective collation of results to produce reliable recommendations (Gough et al. 2012). This research was conducted following the stages typically found in systematic reviews (e.g. Gough et al. 2012, Keele 2007, Wright, Brand, Dunn & Spindler 2007) which are discussed in turn: *Formulating the Objectives*, *Searching the Literature*, *Literature Selection*, *Data Extraction*, and *Data Analysis*.

3.3.2 Formulating the objectives

The four questions investigated in this work relate to the diffusion and application of the script-theoretic approach within but also beyond criminology:

1. Has the script-theoretic approach gained traction since Cornish's seminal article was published?

2. What types of crime have been scripted during that period?

3. What methods have been used to generate and evaluate crime scripts?

4. Under what other names are crime scripts known in (including other disciplines)?

The variables are described in Table 3.1.

Table 3.1: Review questions and variables considered in this work

Review questions	Variables
Has the script-theoretic approach gained traction since Cornish's seminal article was published?	Publications (year, number)
	Authors (year of the first publication related to crime scripts, number)
What types of crime have been scripted during that period?	Crime types scripted or discussed in publications
What methods have been used to generate and evaluate those scripts?	Data sources
	Visualisation models
	Verification & Validation methods
Under what other names are crime scripts known (in other disciplines)?	Synonyms

3.3.3 Searching the literature

The search was conducted through two mechanisms: 1) keyword search (using the wild-card term 'crime script*') of relevant data sources including grey literature

and dissertation databases, and 2) forward citation search based on the primary article in this area: Cornish (1994). The search spans the period starting with the publication of this article and ending in 2016. As shown in Figure 3.1 (page 63), thirteen electronic databases were searched: ASSIA (Applied Social Sciences Index and Abstracts), CINCH (Australian Criminology Database), Criminal Justice Database (ProQuest), ERIC (Education Resources Information Center), IBSS (International Bibliography of Social Sciences), NCJRS (National Criminal Justice Reference Service), ProQuest theses and dissertations, PsycINFO, PsycEXTRA, SCOPUS, Social Policy and Practice, Sociological Abstracts, and Web of Science. In addition, three other data sources were used: Link.springer, Oxford Journals, and Wiley Online Library. These were used in similar projects (e.g., Bowers, Johnson, Guerette, Summers & Poynton 2010, Bowers et al. 2011, Johnson, Tilley & Bowers 2015, Sidebottom et al. 2015) or were flagged when searching through multidisciplinary search engines such as British Library Explorer and Google Scholar. Despite criticisms regarding the use of Google Scholar in systematic reviews (see Boeker, Vach & Motschall 2013), it was used in this review to conduct a forward citation search because the main article, Cornish (1994), was not available in any of the above data sources.

3.3.4 Literature selection

Three inclusion criteria were adopted to screen the identified publications:

Criterion 1: the publication is written in English.

Criterion 2: the publication contains the word ‘script’ in its body AND makes a non-marginal reference to crime scripts.

Criterion 3: the publication concerns the procedural aspects or procedural requirements of crime, as defined in Cornish (1994).

The first criterion was considered acceptable after a search on Google Scholar established that only thirty-four (6%) of the articles identified were not in English. This search was also repeated a year later and corroborated these results. The second criterion allowed a wide range of publications to be considered (including those referring to the terms ‘script’, ‘crime script’, ‘script-theoretic approach’, ‘cognitive script’, or ‘crime commission script’), whilst excluding publications in which these terms only appear in a footnote or reference. The third criterion was used to discriminate between the different meanings of the term ‘crime script’ and discard the publications that have no direct relation to Cornish’s approach — for example, those concerning ‘movie scripts’ or ‘news scripts’ (e.g., Gilliam & Iyengar 2000).

3.3.5 Data extraction and analysis

Publications and authors

All the publications selected in the screening stage were then reviewed by the author, and the following data extracted: study title, publication date, and author name. Based on the annual number of manuscripts published in the period of interest, two cumulative frequency distributions are shown in Figure 3.2. In addition, the list of publications was used to estimate the size of the community by calculating the number of authors who have published on this topic over time.

Crime types

The types of crime discussed in the selected studies were identified in the title or abstract, or, when they were not found there, in the body of the articles. The presence of crime scripts was also looked for within the shortlisted articles by searching for synonyms of the term 'crime script' and looking for diagrams, figures, tables, or narratives that describe a crime commission process. For every identified article that contains a crime script the type of crime that was modelled was recorded. For this, the typology of offences in the *User Guide to Crime Statistics* (ONS 2015) was used.

Data sources and visualisation models

The articles containing an original crime script were examined, and the data sources and visualisation models that were adopted were compiled into a list. Data sources were characterised based on their origins (e.g., primary or secondary data) and types (e.g., police report or newspaper article).

Verification and validation

Information concerning the quality assessment of crime scripts was gathered by searching for possible variants of the words verification, validation, assessment, and evaluation (verif*, valid*, assess*, evaluat*) in the publications that contain an original crime script. The extracted information was then thematically classified based on the criteria proposed by Borrion (2013). New elements, where appropriate, were retroactively added to the list.

Synonyms

Synonyms of the term 'crime script' were identified in an iterative manner, as suggested by Holton (2007). First, synonyms (e.g., offence script) were identified in Cornish (1994). Based on them, a list of related keywords (e.g., offence) was then generated and used (in conjunction with a wild-card character) to identify additional synonyms (e.g., offen*) within the selected articles. When a synonym was found that contained a new term (e.g., scenario in the expression offending scenario), the latter was added to the list of keywords and all selected studies were searched again.

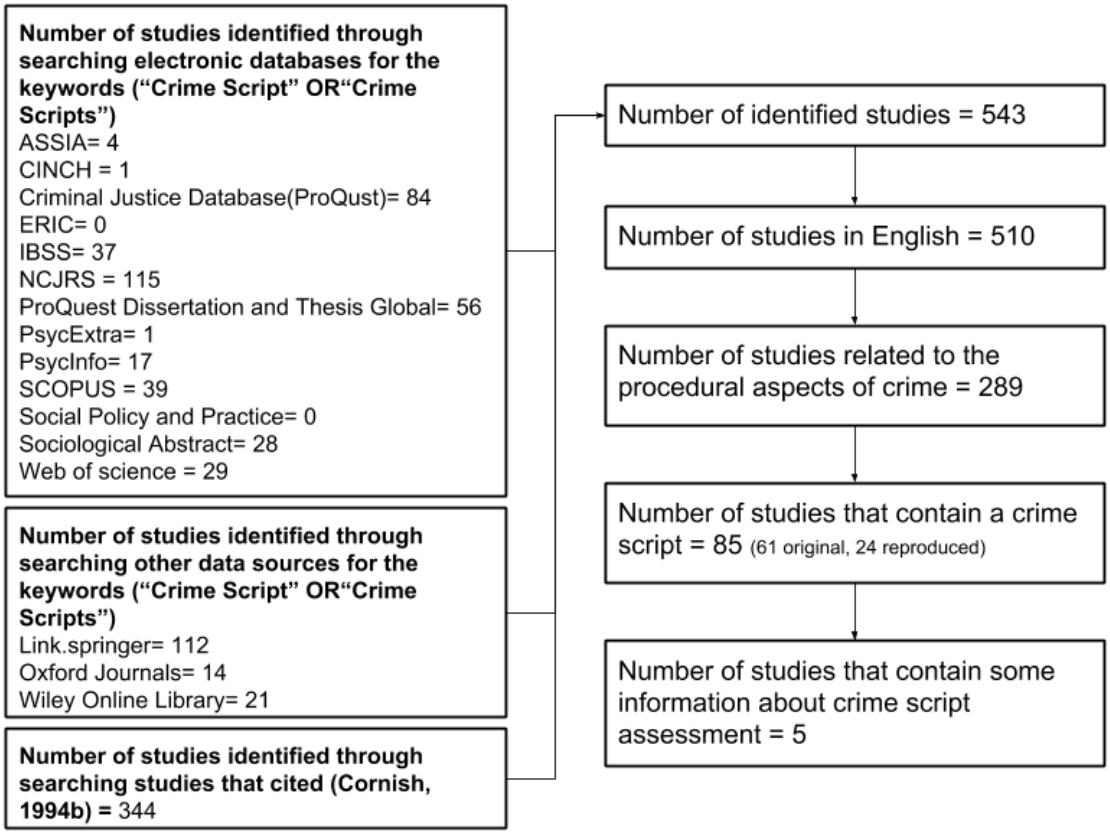

Figure 3.1: Stages involved in the screening process

3.4 Results

3.4.1 Search results

The search strategy described returned 543 publications. The aforementioned criteria were then applied to those studies which resulted in 289 relevant studies (see also Figure 3.1).

3.4.2 Has the script-theoretic approach gained traction since Cornish's seminal article was published?

Figure 3.2 is a cumulative frequency diagram showing the number of publications directly related to crime scripts published between 1994 and 2016. It confirms that the number of publications has increased more rapidly in recent years. In fact, over this period, 80% of the publications were published in the last eight years. Eighty-five of the reviewed publications contained a crime script and in total, 100 original scripts were identified in 61 publications (72%). Those publications were largely peer-reviewed articles (33), followed by book chapters (13), theses (10), conference proceedings (3), and reports (2).

Figure 3.3 indicates that 341 authors contributed to the 289 publications identified as being directly related to crime scripts. The vast majority of the authors (73%) only published one article in this list whilst sixteen (5%) had (co-)authored five or more in that period. This suggests there are very few career crime scripters or fully-fledged crime script experts or that they do not publish all of their scripts. It also shows the number of authors and the number of publications increased in a similar fashion over time.

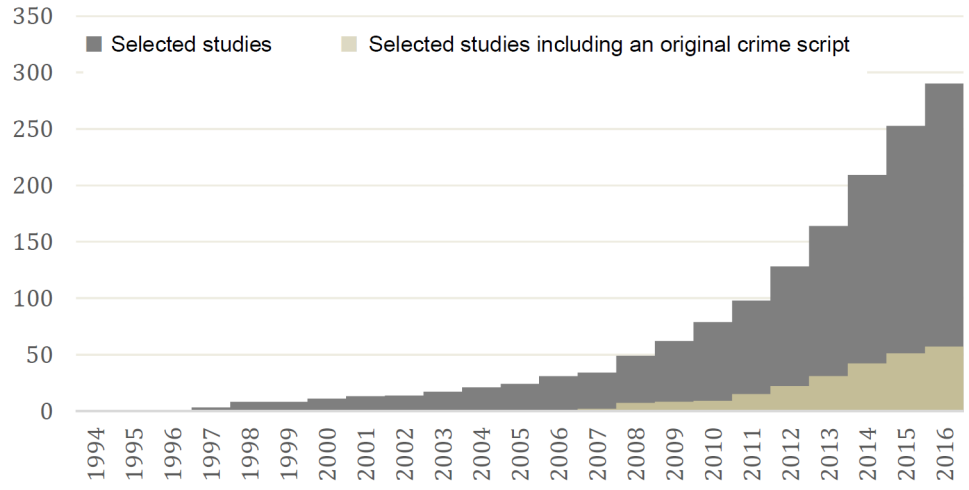

Figure 3.2: Cumulative frequency distribution showing the number of publications mentioning the script-theoretic approach (dark grey) or including an original crime script (light grey), over time (1994-2016)

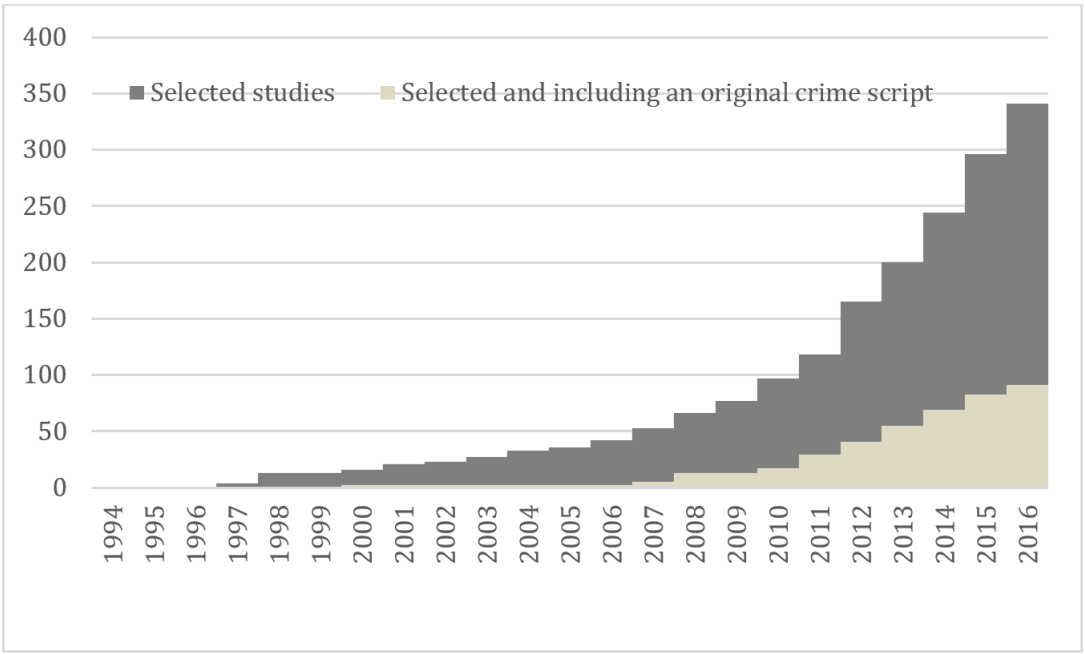

Figure 3.3: Cumulative frequency distribution showing the number of authors of publications mentioning the script-theoretic approach (dark grey) or including an original crime script (light grey), over time (1994-2016)

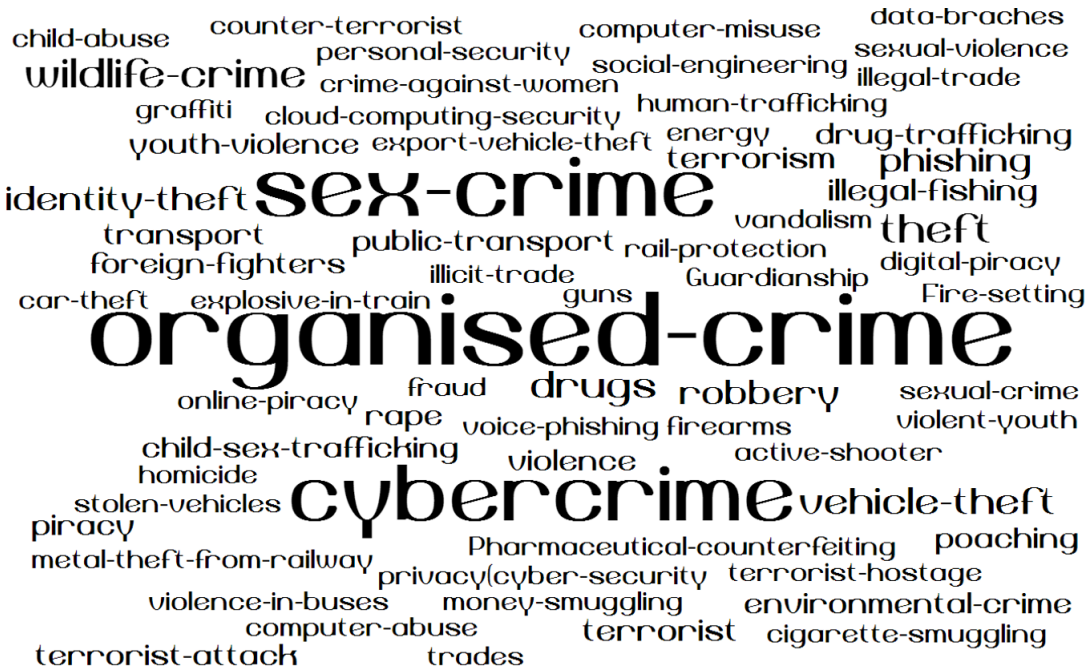

Figure 3.4: The crime types discussed in the selected studies

3.4.3 What types of crime have been scripted during that period?

Not all of the reviewed articles were focused on a particular crime type. For instance, Leclerc (2013) discussed an extension of the script-theoretic approach to victims, without focusing on any particular crime type. Amongst the 289 reviewed studies, about three quarters could be associated to 117 specific types of crime (Figure 3.4).

Focusing on the 100 scripts identified in the search, 62 crime types were found and these could be categorised into 11 broad categories including cyber-fraud (20 scripts), fraud (14), theft (13), terrorism (12) and drug offences (10) (Tables 3.2 and 3.3).

Table 3.2: Crime types that have been scripted

Crime category		Crime type
Fraud	Cybercrime	Account takeover (Haelterman 2016); attacks on online banking (Leukfeldt & Jansen 2015); carding (Meijerink 2013); cybercrime against electricity infrastructure (Rege 2012); phishing (Leukfeldt 2014); physical penetration (Dimkov, Van Cleeff, Pieters & Hartel 2010); (illegal) release process (Basamanowicz 2011); warez release process (Basamanowicz & Bouchard 2011)
	Fraud offences	Corruption (Rowe, Akman, Smith & Tomison 2013); corruption in public procurement of works contracts (Zanella 2013); credit card fraud (Van Hardeveld, Webber & O'Hara 2016); credit card identity theft (Dehghanniri et al. 2015); expense reimbursement fraud (Haelterman 2016); internet-mediated trade in counterfeit pharmaceuticals (Lavorgna 2014*c*); money laundering (Gilmour 2014); pharmaceutical counterfeiting (Kennedy, Haberman & Wilson 2016) stolen card fraud (Haelterman 2016); the process of fraud and other crimes for gain (Levi 2008)
Theft offences		Metal theft from railway (Ashby 2016); pick-pocketing (Gentry 2015); ringing script (Morselli & Roy 2008); robbery (Gentry 2015); snatch theft (Gentry 2015); stolen vehicle pathway (Lantsman 2013); taxi robbery (Smith & Clarke 2000) (Smith & Clarke, 2000); theft from a moving vehicle (Haelterman 2016); theft from churches (Price, Sidebottom & Tilley 2014); theft of electronic products (Ekblom & Sidebottom 2008); vehicle theft (Morselli & Roy 2008)
Violent crime	Sexual offences	Child sex abuse (Leclerc, Wortley & Smallbone 2011); child sex trafficking (Brayley et al. 2011); child sexual abuse (Leclerc et al. 2011); compensated dating (Li 2015); internet-mediated trafficking in synthetic drugs and NPSs (Lavorgna 2014*a*); internet-mediated sex trafficking (Lavorgna 2014*c*); offending process of sex offenders (Beauregard et al. 2007); sexual assault (Beauregard et al. 2007)
	Firearms crime	Trade and use of converted firearms (De Vries 2012)
	Other violent crime	Urban youth violence events (Wilkinson 2011); violent crime (Smith 2008)
Drugs offences		Cannabis cultivation (Duijn & Sloot 2015); clandestine drug laboratoriesdrug manufacturing (Chiu et al. 2011); drug dealing (Jacques & Bernasco 2013); heroin production, importation, and distribution (Le 2013); internet-mediated trafficking in traditional recreational drugs (Lavorgna 2014*c*); online drug trade (Leontiadis & Hutchings 2015)
Environmental crime		Illegal ivory market (Moreto & Lemieux 2015); illegal waste traffic (Dalla Gasperina 2014); illegal hunting, poaching, and illegal wildlife trade (Hill 2015); internet-related criminal opportunities in wildlife trafficking (Lavorgna 2014*d*); internet-mediated wildlife trafficking (Lavorgna 2014*c*); wildlife crime (Lavorgna 2013); waste crime (Tompson & Chainey 2011); wildlife trafficking (Lavorgna 2014*d*)
Terrorism		Crime script for active shooter event (Osborne & Capellan 2015); foreign fighting (De Bie, De Poot & Van Der Leun 2015); explosive in rail carriage (Meyer 2011); shooting massacre (Meyer 2013); hostage taking (Yun & Roth 2008); vehicle-borne explosives (Meyer 2012)
Trafficking		Cigarette smuggling (Hiropoulos et al. 2013); human trafficking (Savona, Giommoni & Mancuso 2013)

Some of the identified crime types could be associated with multiple categories. For clarity, they are only represented in one category in this table.

Table 3.3: Number of scripts per crime category (1994-2016)

Crime type	Number of original crime scripts
Cyber-fraud	20
Fraud	14
Theft	13
Terrorism	12
Drugs offences	11
Environmental crime	9
Sexual offences	5
Trafficking	5
Other violent crime	2
Firearms crime	1
Other	19

Interestingly, cyber-fraud tops this list and this can be attributed to the fact that it is a broad category and covers many crime types. In addition, many academics in cybercrime groups try to find defences against cyber-attacks, which often starts with modelling them. Furthermore, data about cybercrime commission processes may be more readily available in this field where data transfers are more generally logged. It is noteworthy that many offence types do not appear in this table, especially those with low levels of complexity (e.g., dangerous driving); similarly with those that require in-depth knowledge of some niche industry sectors.

3.4.4 What methods have been used to generate, visualise, and evaluate those scripts?

Crime script generation

While this review found no study that describes in detail all the stages involved in generating, visualising, and evaluating crime scripts, it identified several publica-

tions containing information about those stages.

Data sources: forty-nine (80%) of the 61 selected studies that included at least one original crime script, contained information about data sources used to generate the scripts. Three publications indicated that their scripts had been created exclusively from primary data (Rege 2012, Jacques & Bernasco 2013, Li 2015). Twenty-five scripts were created using a mix of primary and secondary data (e.g., Brayley et al. 2011) and twenty-two scripts were created using just secondary data (e.g., Meyer 2011). Eleven publication however provided no information about the data used to create the scripts.

The secondary datasets reported in those publications were collected from both public and private sector organisations. They consist of court data (Chiu et al. 2011); police reports (Brayley et al. 2011) such as offenders' testimonies (Beauregard et al. 2007); interviews of experts and victims (Leukfeldt 2014, Willison 2006*a*); police statistics (De Vries 2012); surveys (Samonas 2013, Willison 2005); and syntheses of open data (Deslauriers-Varin & Beauregard 2010, Lavorgna 2014*a*,*b*, Meijerink 2013).

Visualisation models: three visualisation models have been used to represent the 100 identified crime scripts. The most prevalent are tables with text (65%) (e.g., Cornish 1994), followed by flowcharts with text (24%) (e.g., Cornish & Clarke 2008), and text only (11%) (e.g., Beauregard et al. 2007). Some publications included tables with statistics about the attributes (e.g., space or time) of the crime

commission process and the actors involved. Those tables were not considered as crime scripts because they were not sufficient to understand how the crime occurs.

Crime script assessment

Borrion (2013) highlighted the importance of applying a formal verification or validation process to assess the quality of the generated crime scripts— see also Dehghanniri et al. 2015, Dehghanniri & Borrion 2016, Hutchings & Holt 2015. To validate their script, Brayley et al. (2011) indicated they had used it as a 'stimulus for a structured brainstorming session' aimed at identifying interventions. However, idea generation was not constrained by specific practical considerations and the proposed interventions were not evaluated. Moreover, the lack of a comparison group (such as a group of analysts using no script or a low-quality script) in their study means it is difficult to assess the extent to which the script influenced the outcomes of this process. Chiu et al. (2011) discussed the degree of completeness of their script, indicating that the 'gaps in [their] table reflect script stage-intervention points for which the analysis was not able to reveal sufficient understanding for preventative measures'. They also pointed to some of the limitations caused by the fact that their sample was small and potentially not representative of the population of interest. The main aspect investigated in their study was the reliability of the initial data (data validity), a point also discussed in three other articles (Basamanowicz & Bouchard 2011, Lantsman 2013, Le 2013).

3.4.5 What other names are used for the term 'crime script'?

More than 60 synonyms of the term 'crime script' were identified in the 289 reviewed publications. They were often combinations of very similar synonyms for 'crime' and 'script'. As we can see in Table 3.4, 'crime commission process' is the most common expression after 'crime script'. The first synonym that did not feature in Cornish's reference publication is 'scenario'. In the study, this term was found to be mostly used in the risk analysis and information security literature (e.g., Borrion & Bouhana 2012, Dimkov 2012, Meyer & Ekblom 2012, Willison 2006*b*).

Table 3.4: Synonyms of the term 'crime script', and number of publications in which they appear

Synonym	Number of publications
Crime Script*	221** (76%)
Crime Commission Process*	175 (60%)
Modus Operandi*	124 (43%)
Scenario	67 (23%)
Offender Behaviour*	9 (3%)

*appears in Cornish (1994)
**out of 289 selected studies

3.5 Discussion

Using, usage of, and published crime scripts

The results of this systematic review constitute the first evidence that the script-theoretic approach has been gaining momentum within the research community between 1994 and 2016, as affirmed by Leclerc (2017). Both the number of publications mentioning this approach and the pool of authors have increased rapidly,

with 80% of those recorded in the last eight years of the studied period.

It is noteworthy that the publications referring to this concept are not limited to a few specialist niches. On the contrary, they concern crime types across a wide spectrum, with the rather broad denomination of 'cybercrime' topping the list.

Amongst those, the number of publications that contain at least one original crime script has been increasing in a similar fashion. These trends are encouraging for the dissemination and recognition of the script-theoretic approach, especially as they might reflect an increase in the creation and use of crime scripts by practitioners more widely. The magnitude of those figures is somewhat less impressive. With only 100 original crime scripts, the knowledge published in this area seems incredibly limited.

There are reasons to believe, however, that the crime scripts identified in this systematic review may not be representative of the overall population of crime scripts:

- The scope of this systematic review was limited to those studies published after 1994, and using the words crime script(s) or citing Cornish's reference article. Because of this, only the work of the authors aware of Cornish's work (at the time of writing) was considered in this review. Publications that include procedural models of crime but make no direct mention to Cornish's concept would have therefore been missed in this analysis.

- Because unpublished crime scripts were not taken into account, the total

number of scripts generated in that period could be much greater than our estimates; potentially by several orders of magnitude. Particularly considering that some scripts may have been created but not published due to their sensitivity, for example, where intelligence reports are used as sources of information or where there is a risk that sharing procedural information helps offenders carry out those crimes.

- More extensive backward reference searching strategy (Levy & Ellis 2006, Tada, Kato, Asakawa & Azuma 1998, Webster & Watson 2002) could have been used by searching through all the citations of the selected studies.

Taking all these points into account, it seems a reasonable conclusion that a lot more crime scripts might have been generated than those identified in this review, including some that describe crime types not unveiled here. Paradoxically, the quality of the scripts examined by the authors is likely to be unrepresentatively high since many of the identified publications are peer-reviewed. That said, given the lack of evidence in support of the quality of published scripts, there can be doubts about that of unpublished scripts. To reiterate the findings, many of the published scripts have been authored by academics without evident track record of scripting crime: only 5% of the identified researchers have authored five or more of the identified publications in the studied period.

Performance of the existing crime scripting methods

Little comfort could be found in the reported methodology either. First, most iden-

tified scripts have been generated intuitively, without adhering to a strict and recognised scripting protocol. Second, there was not enough information available to replicate the work reported in those publications; nor to assess the quality of the scripts or ascertain the level of methodological rigour involved in their creation.

Although the published scripts were not accompanied by sufficient methodological details (i.e. specific information about the ways in which they were created), this may be related to poor reporting rather than poor modelling. In fact, legitimate questions could be raised about the usefulness of formalising the crime scripting process. Indeed, the establishment of the script-theoretic approach can already be regarded as an unnecessarily complicated attempt to codify and systematise a practice that has been in existence long before being codified by Cornish. Certainly, it is difficult to imagine how military engineers and security architects managed to create successful arrays of protective measures without framing problems using a script-based approach, and asking questions such as: what steps do most village attacks (burglaries) have in common? What can prevent marauders (burglars) from penetrating in villages (people's homes)? What would they do if defensive walls and watchtowers (fences and CCTV) were introduced around habitats? etc.

All that being said, if crime scripting is useful in finding innovative ways to prevent crime then surely it is worth investing time to think how best to generate, visualise, and analyse crime scripts. To one end, are intuitive methods to think about crime processes suitable or good enough? ... thereby implying that any past or future attempts to explain how to script crime are utterly futile. Perhaps one of

the most useful findings emerging from the review is that I did not find enough evidence to answer this question. Simply put, there appears to have been no attempt to empirically assess the contribution of crime scripting techniques in the two decades that have followed the formalisation of the script-theoretic approach.

Needs to improve crime scripting methods

In this context, I can only acknowledge that more formal crime scripting methods have both advantages and disadvantages. Indeed, it can be hypothesised that providing more structured guidance helps communicating to analysts what the 'crime scripting' task entails. Greater methodological clarity should logically support their understanding of how to script crime, give them greater confidence in the resulting products, and increase their willingness to engage in problem-solving activities more generally rather than blindly opt for existing security recipes that may not be adapted to the problems of interest. Another possible advantage of using structured methods is that poor performance (i.e. inability to identify suitable crime reduction interventions) could be traced back to specific issues in the method that was prescribed or in the way it was applied, and subsequently addressed. Therefore, more structured methods (and possibly some form of standardisation) might be a necessary step to encourage greater integration and comparison of scripts.

However, the use of structured methods is not without arguments. Indeed, the more detail used in crime scripting methods, the more time and resources analysts have to invest in learning and applying them. Thus, making the script-theoretic approach less accessible and potentially curtailing its diffusion (Hardy, Thompson & Edwards

1995, Yourdon Inc. 1993). Although structured methods are intended to be generic (so they can be applied to many problems), there is always a possibility that they do not contain enough detail for scripters to find them useful (Gillies & Smith 2013, Hardy et al. 1995). Conversely, if the method is overly complicated, scripters may not perceive the benefits are sufficient to invest the time learning them, in comparison with alternative in-house or intuitive methods (Hardy et al. 1995, Irwin 1992).

Without evidence that structured methods can yield substantial improvement, 'back-of-the-envelop' scripting might therefore be considered good enough for most problems— even though they could actually offer substantial benefits in terms of identification of crime prevention measures. This is partially examined in chapter 5.

3.6 Conclusion

Searching for publications that contain the keyword 'crime script(s)' or citing Cornish's seminal article in the 1994-2016 period, this review has shown that the list of published crime scripts, whilst only representing a subset of all crime scripts, has grown rapidly since Cornish's seminal article. Characterised by breadth rather than depth, this pool might reach a steady state once a script has been published for most crime types. At that point, a change of direction might be observed, with the generation and quantitative analysis of multiple and more detailed scripts for each crime type.

A wide range of crime types have been modelled using crime scripting techniques including cyber-fraud, fraud, theft, terrorism, drug offences, environmental crime, sexual offences and other violent crime, trafficking, firearms crime, etc. This shows the huge capacity of this crime modelling technique to model various security and crime problems, which suggests a potential future growth in using crime script. Despite this growing market still very little is known about the process of developing quality script. This recommends the need to develop reliable crime scripting methodologies, which is one of the main aims of this PhD research. Before developing such a method, I conduct two studies: i) investigating the weaknesses and strength of the existing crime scripting techniques that would show whether my argument about the weaknesses of the existing scripting approaches is a valid argument or not, and ii) examining a possible improvement on scripting process, i.e. the effects of informing scripters about scripting purpose on scripts quality, which aims to investigate whether telling scripters about scripting goals would improve the performance of the scripting process; these two are represented in chapters 4 and 5, respectively.

Chapter 4

Comparative analysis of crime scripts

In the first part of this thesis, it was confirmed there has been a significant growth in the use of crime scripts between 1994 and 2016. This and the diversity of fields where this crime modelling technique is used, show a potentially large 'market' for a [new] structured crime scripting approach. However, it is not clear yet whether developing such an approach is necessary. Whilst chapter 2 demonstrated that relying on poor quality scripts could affect the identification of suitable crime reduction measures, there is no evidence that shows that existing crime scripting approaches (including intuitive scripting methods) are not already good enough. To address this knowledge gap, this chapter aims to better understand whether crime scripts really depend on those who create them.

4.1 Introduction

To those interested in reducing crime, the practical value of crime scripts is indeed dependent on their format and content. Recently, Borrion (2013) formalised this idea through a list of aspects to be considered when producing and reviewing scripts: typology, traceability, transparency, consistency, context, completeness, parsimony, precision, uncertainty, usability, ambiguity, and accuracy. Many of these aspects are critical to the treatment of crime risk. Ambiguity in scripts, for instance, (i.e. when information can be interpreted in more than one way) could cause analysts to misunderstand crime commission processes and propose inadequate measures. Very low levels of completeness may impede the identification of effective solutions too if, for example, information is missing that would have otherwise enabled analysts to identify additional intervention points.

The quality of crime scripts is a concept built on the premise that some scripts are 'better' than others. Although this might seem obvious, especially after reading the previous reviews in chapters 2 and 3, there is no empirical evidence of this in the literature. The opportunities to assess and compare published scripts are, in fact, very limited— and for several reasons: one way to assess the quality of the results involves verifying how the data were collected and processed. In practice, though, raw data are not conventionally provided by researchers, which makes errors difficult (or even impossible) to detect in published scripts. Another way involves comparing multiple scripts of the same criminal phenomenon, and identify differences between them, as those might also reveal discrepancies in quality. Unfortunately, this second

way is equally difficult to implement as researchers tend to generate scripts about crimes that had not already been scripted, rather than improving existing scripts. In this context, we could even wonder what differences would be observed between scripts produced by different analysts.

Schum (1994) has modelled the credibility of a testimonial process from a human source as a function of three terms: observational sensitivity, objectivity, and veracity. Of greatest relevance here is the former, which refers to the idea that observations can be incomplete or inaccurate. For example, Balcetis & Dunning (2006) highlighted two assumptions about what people perceive from the real world: 'perception is selective' and 'perception is often biased'. In particular, they identified that people's wishes and preferences influence the pre-conscious processing of stimuli in the visual environment and thus 'guide what the visual system presents to conscious awareness'.

To show the shortcomings of intuitive crime scripting approaches and to improve the way of reasoning about the generation, verification, and validation of crime scripts, this chapter carries out an exploratory study adopting a bottom-up method. Relying on the scripts collected from twenty-one participants— all new to the script-theoretic approach— to script a robbery shown on a video footage. Through the analysis of their scripts, it is sought to achieve four objectives that would ultimately contribute to operationalise Borrion (2013)'s concept of quality assessment in this area:

1. Validate a systematic method for characterising the similarities and differences between crime scripts produced by different analysts.

2. Demonstrate that different analysts can produce crime scripts of varying quality and that more prescriptive guidance is therefore needed for this crime analysis technique.

3. Generate some hypotheses as to why certain steps are more likely to be included in scripts than others.

4. Draw practical lessons to improve the guidance and training available to crime scripters.

The following sections detail the method adopted to achieve these objectives, present the results along with their limitations, and list recommendations.

4.2 Method

4.2.1 Participants

A convenience sample of twenty-one Dutch students (19%female) were selected as participants. The age range was from 19 to 28 years old ($\mu = 21$). All students were registered on an undergraduate degree in 'Integrated safety and security science'. They were relatively proficient in English, and unanimously indicated being familiar with the general concept of criminal modus operandi but not with crime

scripting.

4.2.2 Script generation

Materials

Scripts used as illustration in the training phase— In the script collection stage, participants went through three phases: training, training verification, and scripting phases. In the former, the participants were introduced the core principles of crime scripting and exposed to the exemplar scripts represented in Tables 4.1 and 4.2. These were extracted from Cornish (1994)'s seminal article and online training materials used in a crime analysis short course (Tompson 2012). In the absence of standardised instructions, it was decided to select the latter because of their author's track record of publications and training sessions in this area. These scripts were selected because they both represent a form of theft (joyriding and pickpocketing) akin to the crimes discussed in the training verification phase (street robbery) and scripting phase (shop robbery). The scripts are of similar complexity (9 and 10 steps, and one and two actors, respectively), and the crime events they represent common enough to presume that the participants would have no difficulty understanding them. The original scripts were slightly modified to make the author of the criminal acts more explicit, in line with the verbal instructions given to the participants.

Data used in the test phase— The participants generated their scripts based on a 33

Table 4.1: The joyriding script (Cornish 1994)

step no	stage	action
1	Preparation	Offender (O.) gathers tools
2	Entry	O. enters parking lot
3	Pre-condition	O. loiters unobtrusively
4	Instrumental pre-condition	O. selects vehicles
5	Instrumental initiation	O. approaches vehicles
6	Instrumental actualisation	O. breaks into vehicles
7	Doing	O. takes vehicles
8	Post-condition	O. reverses out of bay
9	Exit	O. leaves parking lot

Table 4.2: Pickpocketing script based on Poyner's description of pickpocketing (Clarke & Eck 2014)

step no	stage	action
1	Preparation	Offender (O.) decides to pickpocket at a train station
2	Pre-activity	O. identifies appropriate target in a crowd
3		O. nudges them from behind
4	Activity	O. apologises whilst pocketing the wallet
5	Post-activity	O. exits crowd
6		O. removes cash and credit cards from wallet
7		O. disposes of wallet
8		O. pockets the cash
9		O. takes credit cards to associate to exchange for cash
10		O. spends cash

second video footage representing an armed robbery at a local corner shop. There was no sound in this recording and the scripts were based on visual information from a single-scene & single-shot footage (and their own prior knowledge of robbery events). The file was found on the 'official YouTube video page for the Montgomery County, Maryland Police Department' along with a comment indicating that the event took place at a "7-Eleven" shop on the 12^{th} December 2011 (Mcpdmedia 2011). The robbery event would have lasted more than 33 seconds because the speed of the video had been slightly increased before it was uploaded on Youtube (probably $\times 4$). As shown in Figure 4.1, the image quality is such that the main elements of the scene could be identified within the allotted time. The video was presumably recorded by a stationary colour CCTV camera located inside the shop,

near the ceiling and pointing toward the entrance door. The most visible elements in the footage are the entrance, the shop counter, the customer area in front of it, the offender, and the two employees. Certain parts of the counter and most of the space where the employees stand are less visible because of visual occlusion caused by semi-transparent shelves and other opaque objects.

Figure 4.1: Image from the video footage (scripting phase). The offender (left) is pointing a rifle at the two employees behind the shop counter (right) (Mcpdmedia 2011)

Protocol

Selection— The participants were invited to the university during three hours. Two activities were organised on that day, which aimed to provide them with some background knowledge about crime science. A workshop was conducted as part of those during which they learned about crime scripting. It was supervised by one of the academics who were accompanying the participants during their trip. No financial

incentive was offered for taking part in this task.

Training Phase— The participants attended a 25 minutes training covering the following aspects of crime scripting.

Definition: "A crime script is a step-by-step sequence of actions involved in the commission of a particular crime; including those occurring before, during, and following the main crime event".

Purpose: "To analyse the crime commission process (actions, decisions, and situational factors) in order to identify measures that could potentially prevent or disrupt it".

Technique: A script should describe the sequence of activities performed by, or affecting, the offender and other relevant parties before, during and after a crime:

- Those activities must be listed in a chronological order.
- Activities are different from states; the latter representing the outcome of the former.
- Scripts can span a period of time starting before the main crime event and efforts.
- Scripts should be represented in a tabular format, with no more than one activity per row. The syntax must be consistent throughout the script; where possible each row should start as follows: subject-verb-object.

- Crime scripts borrow various elements from the dramaturgical domain such as the concepts of actors, actions, and props.

Examples: A couple of published crime scripts were provided as illustrations. These include the joyriding and pickpocketing scripts in Tables 4.1 and 4.2. Six participants asked questions about crime scripting; answers were provided to the entire group.

Training validation phase— To ensure that every participant had met the intended learning objectives of the training before entering the test phase, a ten minutes assessment exercise was conducted during which they were asked to generate a crime script for street robbery against a cash-in-transit agent, individually. No additional materials were provided to them at this stage. Review of the generated materials confirmed that all participants had acquired the skills needed to produce a crime script and were therefore eligible to take the test.

Scripting phase— The 33s video footage described in the above section was played in a loop during 15 minutes, on a 42-inch screen situated 2.5 meters away from the participants. The latter were asked to create their scripts on paper. Extra sheets were provided so each participant could write as many drafts scripts as they wished before selecting the best one. All participants completed the task before the end of the session.

4.2.3 Script analysis

The adapted classification approach

The classification system that is used in this research, is an adapted approach for classifying a set of scripted information into a refined list of steps or classes, which was developed based on the work of Berelson, Bernard (n.d.), Burnard (1991), Holsti (1968), Smith (1975), and Berg, Bruce Lawrence and Lune, Howard (2004). The resulting method was close to that proposed by Burnard (1991) for analysing the transcripts of interviews with nurses. This approach has six stages:

1. Listings all the steps of the scripts: Scripts content classification begins by analysing the information found in the first script, dividing them into distinct activities, and creating classes for them. It then continues by determining whether the content of the second script can be classified using the available classes. If not, then new classes are created and added to the list. After that, the third script is processed and so on.

   Three rules are applied in this first stage: i) a script step describing multiple concepts can be decomposed and mapped onto more than one class; ii) the order of the classes is based on the order in which they appear in the script when they are first encountered; and iii) classes could exist at different levels of abstraction, and so, multiple 'micro classes' can be part of one 'macro class' (e.g., 'taking keys out of pocket', 'inserting one of them in the keyhole', 'turning the key anticlockwise', and 'taking the key out of the keyhole' are

all part of the macro class ‘unlocking the door’).

It is recorded which class originated from which scripts— this will be used later to create the classification tables for each script or group of scripts.

2. Splitting the classes: All the listed classes are then reviewed and any decisions to split some of them taken at this stage. This would typically occur when a class i) contains multiple actors, ii) involves multiple locations, or iii) describes multiple distinct actions.

3. Merging similar classes: In the first stage, the steps that relate to the same activities are meant to be associated with the same class. In step 3, this is verified to prevent class repetition and to minimise possible overlaps between classes. Two classes are considered as a repetition if they have a same aim or related action, or the information that exists in one class is already covered by the other one. In this case, the more detailed class is retained and the more general one is double checked to determine whether

   - it is covered by the other classes and can therefore be deleted,
   - it is too general and should be removed, or
   - it can be split into more detailed classes where the process needs to resume at the previous phase.

Burnard (1991) also used same rationale in stage five of his analysis to remove

repetition and similar categories.

4. Filtering out classes: The classes are all individually reviewed to determine whether they are sufficiently unambiguous and detailed, and if it is a step of the crime commission process. Any class that does not meet all these conditions is reviewed to decide whether it should be modified (to satisfy the conditions) or deleted.

   Filtering is done in the same way as was done by Morse & Field (1995), by excluding unrelated information (called 'dross' by Morse & Field).

5. Re-ordering the list: All the listed classes are then compared and re-ordered based on the chronological dependencies between them. This process is done in these strides, recursively:

   - if there is no dependencies between two classes, no re-ordering is required;
   - if a class refers to an action that logically should be performed before another class, the former must appear earlier in the list.

   The comparison is always done between a class and its earlier classes in the list, starting from the last one; same as bubble sort algorithm (Neapolitan & Naimipour 2011).

6. Rephrasing classes: This phase aims to improve readability and coherence of

the list, by re-phrasing all the classes' titles.

To improve the quality of the classification system, the process was performed by two of raters independently, and the results discussed with the third one before agreeing on a final classification system.

4.2.4 Classification of the script steps

Once the classification system was created, the two raters applied it independently to the scripts. Each of them produced a 40 (classes) $\times$ 21 (scripts) binary table. A '1' ('0') in a cell indicated that the script included (did not include) the class. The level of agreement between the researchers was estimated using Cohen (1968)'s kappa, as a measure of inter-rater reliability. The identified differences were discussed between the researchers and resolved to yield a third classification table.

The validity of the classification system and the final classification table was then assessed through two logical tests: If the classification is an accurate and complete representation of the information available in the scripts then it is expected:

- every script step to correspond to at least one class in the classification system, and
- every class in the classification system to correspond to at least one step in the pool of scripts.

Verification was carried out based on the method proposed by Burnard (1991) for

interview data, considering the information omitted, split, or rephrased in the combining stage. However, unlike Burnard (1991) who relied on the participants to verify the scripts themselves, here, a third party for this purpose was used. In the second part of the analysis, it is refined the superscript using the results of the classification. This involved i) identifying areas of uncertainty and conflicts within and between scripts, ii) specifying the information to verify, iii) resolving identified issues using the video footage, iv) developing an 'aggregated-script', and v) verifying the 'aggregated-script'.

4.3 Data analysis

To characterise the differences and similarities between scripts, it is identified the activities and components featuring in the twenty-one scripts, and computed frequency distributions. A score was also computed for every script, as follows:

$$\theta = 1 - \Sigma w_j / J$$

where w_j is a penalty incurred when the j^{th} class is not represented in the script, and $1/J$ a normalisation coefficient with J representing the total number of classes that should be included in the scripts.

The principle behind the above equation is that, for each class omitted in the script, the allotted penalty, w_j, is proportional to the number of scripts that do include it. Finally, it is compared the same steps across several scripts to identify how they differed qualitatively.

4.4 Results

4.4.1 Classes

The resulting classification system comprises 40 classes, that are shown in Table 4.3:

Verification

The classification successfully passed the two aforementioned logical verification tests. Comparison of the classification results reveals the researchers disagreed in only 35 (4%) cases, with a Cohen Kappa coefficient of inter-rater reliability equal to 0.88. Most of the differences were due to a different interpretation of the classification task. For example, one of the researchers associated the activity 'Scare the workers with the gun' to two classes: 'the offender takes a weapon' and 'offender threatens employees (using gun)'. However, the second rater considered that the link to the first class was not made explicit in the script, and had been inferred by the other rater. Other differences in judgement were due to some ambiguity in the script steps. For example, one researcher felt 'offender decides to rob a shop' refers to that particular store and selected the class 'offender selects the shop to rob' whereas the other did not. Overall, it was considered that the two raters were in good agreement.

Table 4.3: The aggregated script resulting from the classification process

step number	crime script step
1*	Offender needs money
2*	Offender thinks how to get cash
3*	Offender decides to commit a robbery
4*	Offender observes various shops
5*	Offender assesses the opportunity at each shop
6*	Offender selects the shop to rob
7*	Offender plans the attack (e.g., time and date)
8*	Offender takes a weapon with them
9*	Offender takes a bag with them
10*	Offender goes to shop location
11*	Offender puts a mask on
12*	Offender waits for customers to leave the shop
13	Female customer leaves the shop
14†	**Offender enters the shop**
15	Two employees are in the shop
16	Offender walks in front of the counter
17	Offender places the shotgun on the counter
18†	**Offender threatens employees using gun**
19	Offender takes the bag out of pocket
20	Offender throws the bag on the counter
21†	**Offender instructs employees to fill in the bag with cash**
22	Offender picks up bag and throws it again on the counter
23	Offender displays aggressiveness
24	Offender walks along the counter
25	Offender observes employees' actions
26	Male customer opens the door
27	Offender threatens the customer
28	The customer leaves the shop
29	An employee puts cash in the bag
30	Offender feels he is running out of time
31†	**Offender takes the bag from the employees**
32	Offender looks at the content of the bag
33	Offender threatens employees before leaving
34†	**Offender leaves the shop**
35	Employee looks in the street if the offender has left
36	Employees calls the police
37*	Offender gets rid of the weapon and mask
38*	Offender gets home safe
39*	Offender decides what to do with the money
40*	Offender spends the money

* Correspond to the events not directly represented in the video footage

† Found in more than 50% of scripts

4.4.2 Scripts analysis

Classes number 13 to 36 correspond to events represented by the video footage whereas the first twelve classes and last four classes correspond to events that occurred before and after the scene in the shop, respectively. The median number of classes described in the scripts is 6 for the period corresponding to the scene of the shop, and 8 overall.

As represented in Figure 4.2, five (12.5%) of the 40 classes are found in more than 50% of the scripts. These are classes number 14, 18, 21, 31 and 34 (in bold in the table), with 14 and 34 mentioned in almost all scripts. Nineteen (47.5%) of the 40 classes are found in one script only.

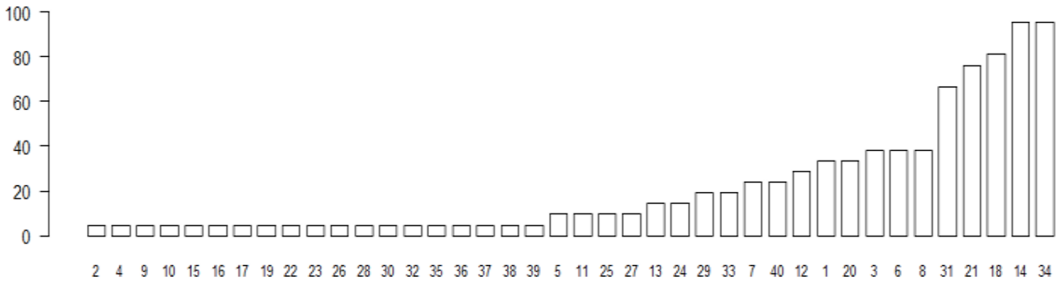

Figure 4.2: Distribution of script steps across the forty activity classes (%)

A completeness score was computed for each script and represented in Figure 4.3. A linear regression line was estimated for the twenty-one data points. It was found that the number of classes a script includes is a significant predictor for its score: β=0.0057 ($p < 0.05$). The overall model fit was relatively poor with $R^2 = 0.35$.

Components: Twenty-six components were identified in the pool of scripts as shown in Table 4.4. As represented in Figure 4.4, the first eight (31%) of twenty-six com-

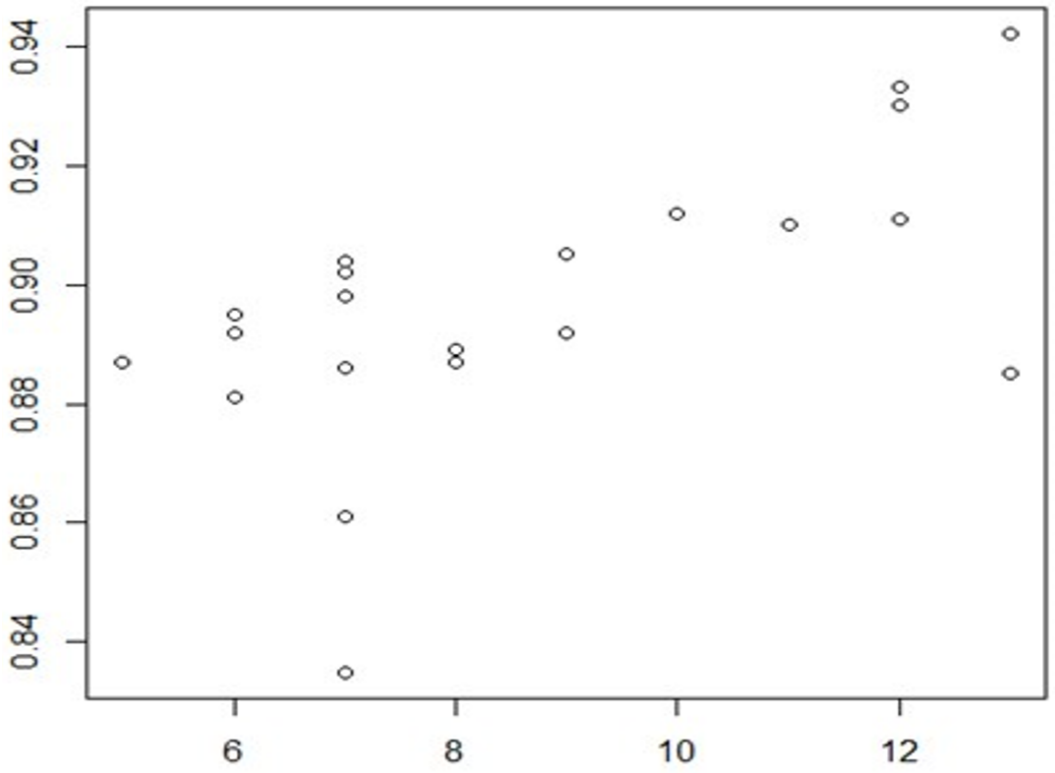

Figure 4.3: Relative level of completeness (y) computed using the equation $\theta = 1 - \Sigma w_j / J$ as a function of the number of steps (x) (N=21)

ponents (in bold in the table) are found in more than 50% of the scripts. Six (23%) components are found in one script only.

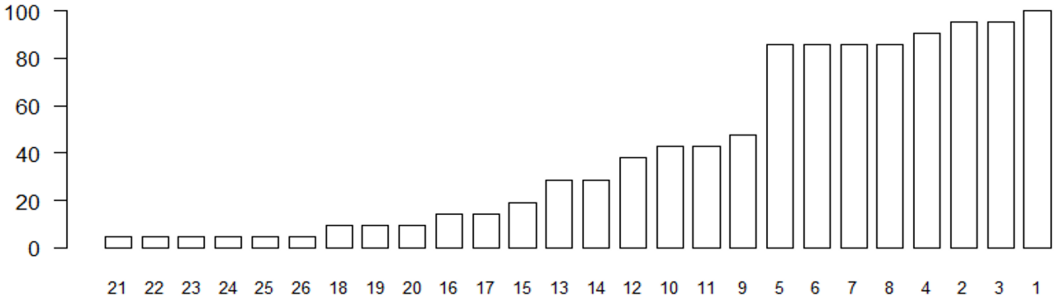

Figure 4.4: Main components and proportion of scripts that report them (%)

Table 4.4: The components identified within the collected scripts

number	crime script component
1†	**Shop**
2†	**Money**
3†	**Weapon**
4†	**Employee**
5†	**Bag**
6†	**Entrance**
7†	**Order**
8†	**Threat**
9	Observe
10	Exit
11	People
12	Customer
13	Movement
14	Plan
15	Aggression
16	Mask
17	Surveillance
18	Assessment
19	Counter
20	Vulnerabilities
21	Checking
22	Money holder
23	Pocket
24	Police
25	Time
26	Vanishing

† Found in more than 50% of scripts

4.5 Discussion

4.5.1 Findings

1. Different scripters create different scripts when they use an intuitive scripting method: The results unambiguously show that when several individuals who received the same training about crime scripting, watch the same video footage of a crime, and use an intuitive scripting approach, their scripts can greatly vary. The scope of the scripts and the number of steps, activities, and components comprised in the scripts all vary between scripters. The amount

of details in the description varies too, with some participants summarising a set of activities as a single macro-step whilst other break them down into several micro-steps.

2. There are patterns amongst the most prevalent steps: Whilst this study confirmed that the diversity of information provided by multiple scripters can help build more comprehensive scripts, it was noticeable that only five classes and components were identified by at least half of the participants that are steps 14) Offender enters the shop, 18) Offender threatens employees using gun, 21) Offender instructs employees to fill in the bag with cash, 31) Offender takes the bag from the employees, and 34) Offender leaves the shop. (Note: the scripts that include steps related to these classes do not include all the details provided here).

   So why are those activities the most prevalent amongst the resulting pool of scripts? Providing an in-depth answer to this question is beyond the scope of this research. Nevertheless, four observations can be made at this stage that might be helpful to generate new research hypotheses:

   - The most prevalent classes all refer to the offender's actions, and other actors are mentioned only when they are involved in those too. This is possibly due to the widespread interpretation of crime scripts as criminals' scripts, and the fact that participants were shown examples of scripts that focus on the offenders' actions during the crime (Kaplan,

Haimes & Garrick 2001). A different set of scripts could have been obtained if the other actors had been emphasised in the training phase, as suggested by Leclerc (2013).

- Taken together the most prevalent classes describe how the offender's proceeded to obtain their reward (i.e. the cash). This may have been perceived by the participants as the main (if not sole) objective of the offender in the video. Activities that relate to their other goals (e.g., not being identified, caught or harmed, and not 'having to' physically harm anyone) were only rarely reported by the participants. For example steps 13) 'Female customer leaves the shop' and 33) 'Offender threatens employees before leaving' are both visible and important activities since they are likely to have influenced the offender's decision (whether and when) to enter in the shop, and the employees' decision not to alert bystanders for example. However, only a few participants reported them. This is arguably the most important finding of this study as it suggests that the informative value of crime scripts depends on the scripters' perception of their function (for instance, explaining how the offender managed to achieve the crime vs. explaining what the various requirements were and how they satisfied those during the crime commission process).

- Within the five most prevalent classes are steps corresponding to the scenes *Entry*, *Doing*, and *Exit* elements of Cornish (1994)'s universal

script. Given that participants tended to describe how the offender managed to achieve their main operational objective, it could be expected that the 'Doing' stage will appear in most scripts. The reason why the 'Entry' and 'Exit' steps were also frequently included could that participants may naturally be inclined to open and close their narratives. This idea has been developed by Ryan (2004) who wrote that 'beginnings and ends are introduced in the taleworld by the storyrealm thus rendering consequential what is merely consecutive'.

- Finally, it should be noted that the classes most commonly found in the pool of scripts also correspond to the steps that are visually highly noticeable. In film studies, four types of relationships are commonly discussed between shots— spatial, temporal, rhythmic, and graphic (Toolan 2012). Discontinuities in those dimensions (and in particular movements of the main 'objects' were proposed to generate a computerized 'narrative abstraction model for story- oriented video' (Jung, Kwak, Song & Lee 2004).

3. Why recurring actions should be written multiple times: It also appears that when an action occurred more than once (e.g., throwing the bag, threatening employees), very few participants wrote it down more than once. This may affect the result of the analysis, particularly when the reason for carrying out the recurring activity change over time. In the video, for example, it is likely that the purpose of threatening the employees was initially to persuade them

to swiftly hand over the cash without resistance. However, in the last instance, it is likely that the offender threatened them to dissuade them to follow him or alert bystanders as he was leaving the shop. Recurring activities should therefore be recorded more than once to avoid reducing the informative content of crime scripts.

4. The more steps, the better (and why this is not evident): Without examining which scripts can better assist in the development of control measures, it is difficult to make a judgement about their informative quality. Using the proposed scoring method to assess the scripts levels of completeness, it was observed that the scripts' level of completeness was positively associated with the number of steps they comprise. This was not necessarily the case because the scoring method weighs the classes differently (see the equation on page 91). An opposite result could have been found if, for example, the classes in the shorter scripts happened to be the most frequent ones, and those in the longer scripts the less frequent ones.

5. Some steps are not based on factual observations: Some scripters included not only observed facts but also their interpretation of the actions. For example, Script number 16 includes the following step: walks in with a gun and holds [it] tight in the direction of the employees to scare them. They do not restrict the step to a description but also include their understanding of the offenders motive for doing so. Likewise, the step 'Offender says they want to have the money put in the bag' is not directly extracted from the video

since there participant did not have the corresponding audio track. This point was made by Ekblom & Gill (2016) in that 'but even the most determinedly empirical descriptions of behavioural regularities will adopt the intentional stance (Dennett 1987) or theory of mind (Goldman et al. 2012)'.

6. Scripts have different beginnings and ends: Finally, several scripts included actions that would have occurred either before or after the period depicted by the video. Whilst those details are relevant to understand how the crime could be prevented, they are not evidenced by any of the supplied materials, and should be treated differently in the analysis. As a general point, the scripts should have indicated whether the information was obtained through observation or abductive reasoning.

4.5.2 Limitations

The quality and diversity of crime scripts are dependent upon a number of elements including the crime to be modelled, data source, deployed crime scripting method, and crime scripters. To address the four objectives of this study, design choices were made with respect to those three elements: Robbery was selected as a crime type because it is very common and does not require scripters to have extensive domain knowledge, unlike certain types of cyber-fraud for example. A video clip (without sound) was chosen as a data source because recorded clips show the information in an identical manner every time. Moreover, videos are less leading materials that give participants some independence in structuring their crime scripts, selecting the

elements to include in the model, and describing them— in comparison with narratives, for example. The fact that only one video was used is a limitation of the study, as the results may not be generalisable to videos that have more or more complex scenes. In terms of external validity, the study has a number of limitations that might affect the generalisation of the results. First, the participants were crime science students in their early twenties, with limited knowledge in the field of crime and crime prevention/detection and no prior experience of crime scripting. The script contents might have been very different if participants had been analysts with much greater expertise in this field. For example, their scripts may have been more similar and more complete. Second, English was not the first language of the (Dutch) participants. Because of this, they may also deviate from traditional crime scripters whom would normally be asked to write script in their first language. It would be expected that analysts use a wider set of technical words to write a script in their own language (Chamcharatsri 2013). Third, the participants were largely male (81%) and the results may have been different with a more gender-balanced sample. While there is no evidence that suggests male and female analysts write scripts differently, gender may be correlated with other characteristics (e.g., personal experience or areas of interest) that may indirectly influence information selection (Albin, Benton & Khramtsova 1996, Dampier, Kelly & Carr 2012, Herring & Paolillo 2006). Nevertheless, the sample appears to be representative of the current target population in terms of gender alone, as statistics show that 70% of UK police officers are male (National-Statistics 2018).

4.6 Conclusion

This exploratory study of video-based crime scripting practice involved comparing crime scripts produced by different analysts and statistically characterising their similarities and differences. The application of this method to a set of robbery scripts have confirmed that different individuals produce scripts of varying quality, thereby evidencing the limit of intuitive approaches to crime scripting. It can be implied that the quality of intuitive scripts depend on their scripters' quality, e.g., personal knowledge, experience, understanding, bias, and interests. This is a real threat against scripts' quality suggesting intuitive scripts are not always reliable. It recommends the needs for developing a structured, more systematic crime scripting technique (e.g., a goal-driven script elaboration) that could outperform the current intuitive approach, and reduce the observed variance in quality. Providing a step-by-step method may give scripters a better understanding on how to write quality scripts, provide them a greater confidence in their results, and encourage them to publish their scripts.

Implying from the results, it also could be seen that some steps are more likely to be in scripts than others, including the fact that many scripters would focus on what the offenders do to achieve their primary objective (i.e. robbery) discarding considering other relevant actors or goals (e.g., not being caught, etc.). Deploying a goal-based scripting strategy that involves a wider range of stakeholders/actors in scripting would be a possible solution for this problem. This provides scripters with a wider range of goals and actors and some level of interpretation to indicate

whether the elements included in their scripts correspond to their scripting purposes and observed/reported events.

If crime scripts are intended to be used for a specific purpose (i.e. goals), crime scripters should be trained to better identify the relevant information to those goals. For the goal of crime reduction, crime scripters should be trained about the elements that can help to i) specify effective control measures with limited negative consequences, and ii) assess how suitable they would be if they were to be implemented. This also can be gained by following a goal-driven scripting approach that provides more specific and detailed scripting and quality assessment instructions.

Goal-driven methods have been used successfully in different fields of studies (e.g., requirements engineering) and can assist in development of a new structured and systematic crime scripting method, which covers different stakeholders and clarifies various development stages, but the benefit of such methods on crime scripts quality as the final product of potential goal-driven crime scripting practices is arguable. To investigate this, and before developing such a method, this PhD investigates whether involving goals in crime scripting process would improve the quality of generated crime scripts, regards to the application in which the generated scripts will be used in. This investigation is conducted in an experiment that is presented in the next chapter.

Chapter 5

Examining the effects of goals on the content of crime scripts

This chapter examines an important aspect of the crime scripting process: information selection. As explained in chapters 2 and 3, there appears to be limited information about *how scripters decide what information should be included in their scripts* and *what might influence their decision*. The chapter starts with a review of the literature examining how this issue is addressed in other areas that have also investigated information selection: e.g., psychology or advertising. Next is a review of this practice in the crime script literature. This chapter then continues with the description of an experiment conducted to empirically test whether *the content of a script is influenced by the stated purpose of their crime scripting task*, referred thereafter as the 'goal(s)'. This section covers the experimental method, including details about the participants, materials, data collection, data coding and data anal-

ysis. This then is followed by a description of the results and a discussion of the main findings, including their implications and limitations.

5.1 Information selection

5.1.1 Definition and purpose

'Information selection refers to people's tendency to make a selection from the total amount of information they have at their disposal' (Mors 2009). This concept has been investigated in various fields including advertising (Ford, Kraft & Tewari 2003), psychology (Schellings, Van Hout-Wolters & Vermunt 1996), human sciences (Hockey & Hamilton 1970, De Bruin & Van Lange 2000), ontology (Khan, McLeod & Hovy 2004), computer science (Gazdzinski 2012), and text analysis (Filatova & Hatzivassiloglou 2004). While these fields will have various applications of this process, they have a very similar objective: i.e. selecting (only) useful information for their application. Khan & Luo (2002) expressed this in terms of two key problems: 'to guarantee delivery of minimal irrelevant information (high precision) while ensuring relevant information is not overlooked (high recall)'— Borrion's parsimony and completeness criteria in crime scripting field (Borrion 2013).

5.1.2 Factors that affect the crime scripting process

The way information selection is performed is likely dependent on a number of factors, such as the amount of time spent on the task, method, instructions and

tools used in the task, the number of people involved, their skills and experience, instructions, and the available data. Many of these factors however depend on the resources available to the 'information selector' (e.g., time or available data) and so can be difficult to change. Others (e.g., the instructions provided to them or the methods used to identify information) can however be modified more easily. As such, these latter factors will be investigated in the remainder of this section by looking at information selection in different fields of studies.

Scripters and their personal features are one of the main factors that affect the results of information section. This has been examined in various studies and from different perspectives. For example, Hortaçsu (1987) investigated whether age affects what is being selected by people in an information selection task. She ran an experiment to assess how children of different ages (i.e. 9, 12, 15, and 17 years old) select information in a defined task. Her results suggested that older children selected information that is more closely related to their tasks. Jacobs, Bennett & Flanagan (1993) studied the influence of family structure on people's decision making and information selection. Their study suggested that people who grew up in mono-parental families were more likely have more autonomy (and are more biased) in their decision making, while people who grew-up in two-parent families were more likely to consider the preferences of the group. Winter, Kramer, Appel & Schielke (2010) pointed out that when it comes to selecting information, people tend to make decisions based on the credibility they give to a (source or) piece of information—which is itself based on their knowledge, experience, interest, and bias. Evans

& Poole (1986) conducted a study that suggested that factors such as deployment strategy and the information selectors' personal differences (e.g., culture, language, skills, and experience) affected the results of information processing and selection process. Moreau & Coquin-Viennot (2003) studied the ability of children (9 and 10 years old) in information selection in problem solving and found that children that are clearly tasked were more likely to make a valid distinction between the information indispensable to a problem and other information.

In the field of psychology, Schellings et al. (1996) also investigated the factors that affect information selection. Their study examined how different instructions affected information selection in texts: i) *linguistic approach* where the main information points are selected based on the structure of the data (e.g., text or context structure) and what has been covered by the authors of that data, ii) *educational approach* where a piece of information is selected depending upon their relevance to some instructions (e.g., objectives, task demands, and/or questions) and what was explicitly asked in the task, and iii) *cognitive-psychological* approach where the personal variables (e.g., personal goals and interests) ruled whether a piece of information is selected or not. Their work showed that the approach followed by participants had a direct positive relationship to the type of information selected. That is with the linguistic approach, most of the selected information depended on the provided data (e.g., text), its structure, and what authors had covered. In the educational approach, most of the selected information depended on the objectives of the task. Lastly, with the cognitive-psychological approach, most of the selected

information is related to the person's personal knowledge, experience, and interest.

The above three approaches are not mutually exclusive and could be affected by each other. For example, cognitive-psychological approach may be implicitly used in any information selection process, which means information selectors personal goals, interest, experience, and biases may affect the selection process. Cerdán, Gilabert & Vidal-Abarca (2011) explored these dependencies when searching in texts, and questioned the influence of individual skills in answering questions. Their research aimed to investigate purposeful or goal-driven information seeking (e.g., reading text) where information is sought based on a defined task-oriented approach and to compare this with traditional comprehension of data. Although this work identified that with the task-oriented method specific pieces of information were sought, selected, and processed according to the task's demands; but it also concerned the skill/experience of the information selectors. An experiment was also run in this study that compared two groups of skilled and less-skilled information selectors in identifying related information. The results suggested that 'skilled comprehension facilitates the use of idea-based selection of information strategies, whereas less-skilled comprehension induces the inappropriate use of [task-matching] selection of information strategies'. This supports the idea that personal biases affect information selection activities.

Similarly, Salisbury, Laincz & Smith (2012) investigated the same problem from a different angle. They studied how training and prior knowledge affected information selection. Their study experimentally assessed how attending a library in-

struction session affects the choice of library scholarly database for information selection by students. Their results suggested that the information seeking strategy of students would improve if they were trained about methods for searching information and sources for seeking information.

Likewise, representers' cognitive skills also affect the quality, length, and clarity of an event representation. This was shown by Boudreau & Chapman (2000) who examined the relationship between the event representation and linguistic skills of children and adolescents with Downs syndrome. The participants were presented a short wordless video and then each participant retold the story to an adult who [presumably] had not seen the film. The main findings were that participants with lower verbal skills produced narratives that were significantly longer and more complex comparing to expressive-language— matched participants.

Videos are one of the main sources of information and are used in different fields, such as crime investigation (CCTV footage), advertising (TV advert), and automated video processing (identifying objects). Information selection from video media was studied by a number of authors including Lin, Gong, Li & Wang (2009) who studied the challenges in representing and recognising complex semantic events (e.g., illegal parking or stealing objects) to gain a high-level understanding of video sequences. They addressed key problems that have been studied in the literature related to information selection from videos, including background modelling (Stauffer & Grimson 1999), object tracking (Li, Gong, Zhu & Sang 2007), object detection/classification (Li et al. 2007, Zhu & Mumford 2007), and illumina-

tion/occlusion problems (Haritaoglu, Harwood & Davis 2000). This study introduced an attribute graph model for [video] events modelling to provide a meaningful understanding of video sequences. In their work, object tracking was a key component of information selection.

Moreover, a gap between low-level measurement (e.g., segmentation, object classification, or tracking) and high-level understanding of video sequences was addressed by Hakeem, Sheikh & Shah (2004) who introduced a representation of events in video based on natural language and adopted a hierarchical procedure for information selection. Their method had three key contributions. First, it recognised the importance of cause and temporal relationship between sub-events, which allows the representation of temporal structures and causality between sub-events. Second, it provided a hierarchical representation of events in terms of sub-events and case-lists for capturing multi-agent and multi-threaded events. Lastly, and for the purpose of presentation, it presented the concept of event-tree.

Regardless of the method used to select information, it is normally the case that the media or interface used for representing information has some limitations. An evidence for this is a study conducted by Lang, Dhillon & Dong (1995) about the elaboration of narratives for the video and audio components of television programmes. They highlighted 'many of the variables that influence memory (e.g., education, interest, or viewing environment) cannot be controlled by [TV] message producer'. This suggests some deficiencies within the data that are used as the main source of information in an application. Nevertheless, there are other factors that can be con-

trolled to improve these defects, such as difficulty (Thorson & Lang 1992), pacing and complexity (Lang, Chaffeur, Davidson, Funabiki & Reeynvaan 1992), arousal (Lang et al. 1995), completeness (Meadowcroft & Reeves 1989), and chronological order (Lang 1989).

Information selection in crime scripting

With respect to crime scripting, information selection relates to a simple but critical question: *what (type of) information should be included in the script?* Different aspects of an information selection activity should be considered to provide an adequate answer to this question. For example *the characteristics of the information that is sought in an application*, in terms of the type of information and its relevance to the application. Considering Borrion's (2013) criteria, and as script content is the main material to evaluate the validity of the final script, here we may need to add some other criteria to completeness and parsimony that were addressed in Khan & Luo (2002), e.g., traceability, or correctness. That said, the importance of these criteria might be different in different works or applications.

The characteristics of information in crime scripts

What type of information is sought in crime scripting? The problem of information selection was considered in various fields. Gardner (1987), for example, examined issues about gathering and organising information to describe events, e.g., visual processing, mental imagery, classification, and rationality. Labov (1972) discussed various forms of temporal and/or causal sequences [of sub-events] in presenting

narratives and also more complex forms that may contain additional elements such as orientation. He looked at different items e.g., identifying the time, place, people, their activity, and situation in describing an event.

In a similar way, Cornish (1994) pointed to some features of the information required for constructing a crime script, e.g., information relevant to situational crime prevention, crime commission, modus operandi, and typical behavioural routines and lifestyles available and operate in particular crime incidents. He wrote that 'for potential offenders, the choice-structuring properties of crimes translate into motives, needs, skills, preferences, and values which may influence [offenders'] choice of one crime over another with similar goals, particular methods of crime commission, particular categories of targets or victims, and undertaking the crime in question on a particular occasion'. As discussed in Chapter 2, he also suggested specific types of elements to be included in scripts, e.g., actors, actions, locations, skills, knowledge, etc.

What information is relevant to crime scripts? In an article about individual differences in information selection, Schellings et al. (1996) pointed out that 'not all the information is equally important for building an appropriate representation'. They questioned the importance of different types of information. They suggested that searching for relevant information is an essential step both in comprehending and in learning. Other studies however argue about this and some of the key studies are described next.

Related to crime scripting, Cornish (1994) discussed the *importance and relevance* of information to crime commission description. Following this work, the importance of the spatio-temporal aspects of crime commission and the need for a detailed understanding of where (along with when and how) were highlighted in his work. He also discussed what information is more important in describing the crime commission process and noted 'the importance of the immediate circumstances within which criminal activities take place'. In doing so, the dependency of criminal events upon convergences between motivated offenders and situational opportunities for crime should also be considered (Brantingham & Brantingham 1984, Cohen & Felson 1979, Cornish 1993). For many situational prevention purposes, however, an effective crime script would contain relatively well-elaborated information gained using effective methods that stands on patterns of action-in-situations that commonly contribute in crime events (Cornish 1993, 1994).

Information selection in the crime scripting literature

Intuitive methods: Intuition is the ability to grasp a situation or information without the need for reasoning. The opposite of intuitive decision making is rational decision making, which is when individuals use analytics, facts and a step-by-step process to come to a decision. Concluding from the reviews presented in chapters 2 and 3, it seems the intuitive method is the most popular approach to crime scripting as most of the studies producing a crime script did not mention any specific scripting procedure. As a result, it can be implied that scripters mostly use intuitive methods, relying on their personal experience and knowledge.

Template based methods: Although most of the studies reviewed in the systematic review in this thesis appear to have used the intuitive approach to develop their scripts, a few studies describe some basic structure for crime scripting, e.g., in forms of hints, patterns, or procedures. For example, to construct scripts, Cornish (1994) explained that variation and elaboration of crime scripts involve the extension of one or more scenes in the script and then populating steps by describing their relevant actions to achieve a meaningful crime script. This is by considering crime scripts' components (e.g., actor, action, location, skills, knowledge, etc.). His proposed process is a static template idea (i.e. universal script) for elaborating scripts. Some other studies used dynamic templates where they first, identify the crime scenes (based on their specific crime type and its application) and then populate scenes with relevant steps to develop their scripts (see e.g., section 2.2.3 or Brayley et al. 2011, Cornish & Clarke 2008, Tompson & Chainey 2011).

5.1.3 Gap

Concluding from the above review, three main factors affect what is selected in an information selection process: i) *data and data structure*, ii) *information selectors' personal experience, interests, and/or biases*, and iii) *task demands*. The main concern of this thesis is to improve the process of crime scripting to improve the quality and relevance of the generated crime scripts. From the above three factors, the first two are out of scope for this work— the first factor is about the data which is independent from the crime scripting process itself, although this process can

evaluate the provided data and demand complementary data. The second is about the scripters' personal experience and biases which is not directly related to the crime scripting process, although this process can potentially control the biases or mitigate this risk that the biases negatively affect scripts content. The third factor is about the task's demands and concepts such as scripters given instructions, goals, or guidelines. Tasks demands is directly related to the crime scripting process and can be controlled/defined.

This chapter explores a possible improvement for task demands which is involving of goals in information selection. More specifically, it is explored *whether the knowledge scripters have about the future application of a crime-script-to-be affects its content?* This knowledge is the crime scripting goal which describes why a crime script is being developed, what is expected to be in a script, or where the script will be used. This exploration is accomplished by examining the below hypothesis:

> **Hypothesis**: Crime scripts are more likely to contain relevant information when scripters are aware of their intended application.

A question that may be raised here is that *what is a goal in the above hypothesis?* Here, a goal describes an expectation, requirement, or purpose of an application. A crime script is usually developed to help in identifying SCP measures. This though is arguably too general. Having more knowledge about the application of the crime-script-to-be would help to define a more specific goal. For example, let us consider a security problem that has been recently reported in a UCL department where an

individual tailgated the department's visitors and gained unauthorised access to the department's building and stole from the department. To tackle this security problem, an application is defined that its purpose is to identify and implement some security measures (i.e. SCP measures) to mitigate the risk of unauthorised access to the building e.g., via tailgating. So, here, a goal for such an application can be defined as: 'To prevent unauthorised access to the building'.

5.2 Experiment

This section describes the experiment conducted to examine how scripters knowledge about the application's goals affects crime scripts' content. When scripters are aware of the goals of the application, they would be expected to include more of the information related to that goal(s) (and less unrelated information). Here, the hypothesis mentioned in the previous section is tested quantitatively in an experiment that consists of the following stages: i) *recruiting participants*, ii) *collecting the required data*— i.e. crime scripts, iii) *coding and analysing* the collected data, and iv) *testing the hypothesis*. This is illustrated in Figure 5.1. Specifically, this experiment uses an *experimental design*, which controls the condition in which scripters construct their scripts. The experiment includes three groups of scripters who are each asked to write a crime script for the same crime event while they are given different crime scripting goals.

In designing this experiment, some of the factors that may affect the final results are considered including the participants' characteristics (e.g., academic background,

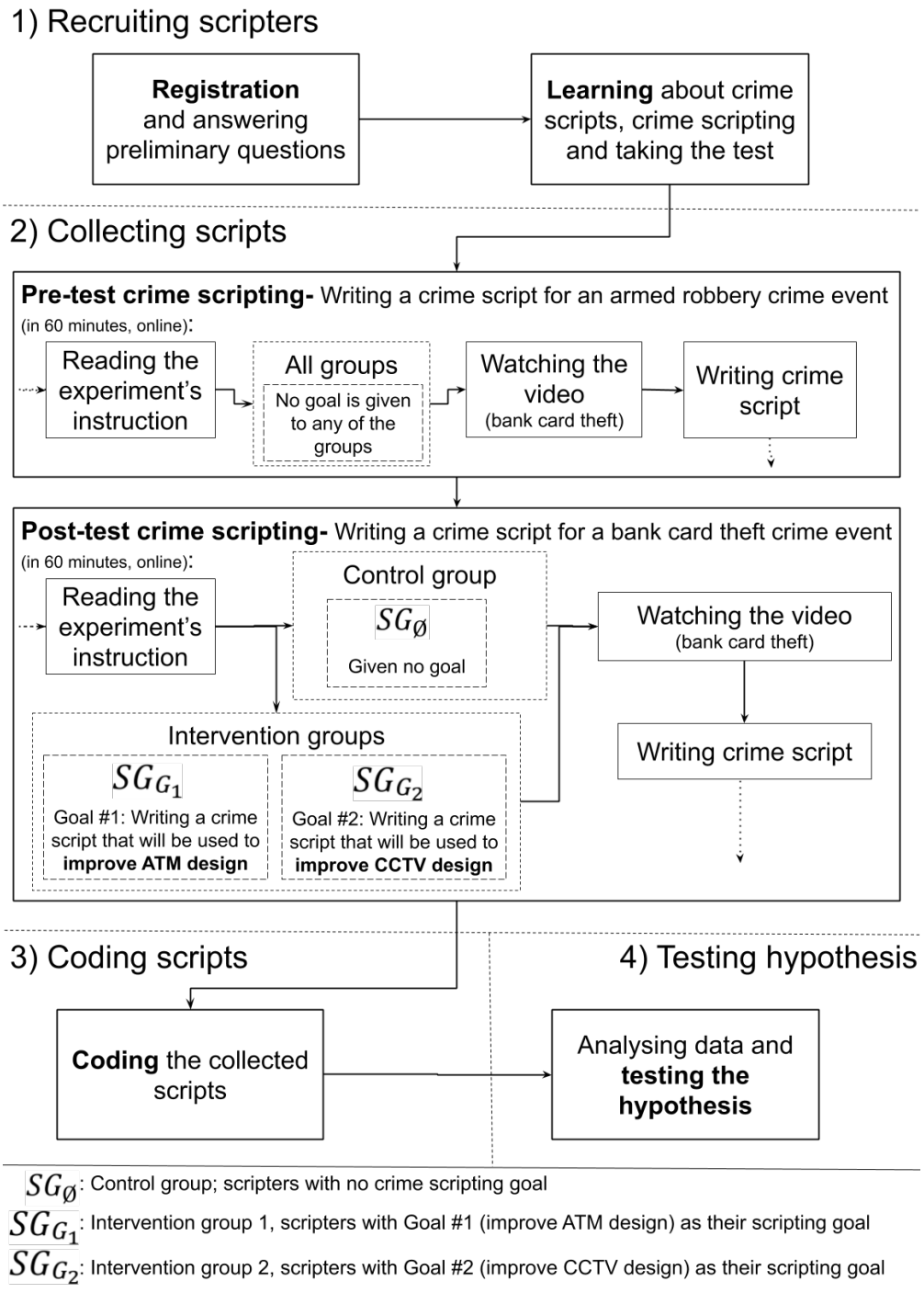

Figure 5.1: Goals effect experiment design

language, crime scripting experience, and crime prevention experience) and the experiments' characteristics (e.g., amount of time participants have for completing their tasks, scripting environment and tools, provided data, procedure, training materials, and crime scripting method). The full list of the factors considered in this experiment are shown in Table 5.1 and are all controlled for the experiment. Apart from these factors, two other factors that could affect the scripts' content are considered as the independent and dependent variables of the experiment:

Independent variable: The scripters knowledge about the application's goal(s),

Dependent variable: The presence of a step in a crime script when that step is relevant to a specific goal— here a step is unbreakable and cannot be split into multiple steps.

5.2.1 Method

Participants

For this experiment, 133 postgraduate students were invited from four Security and Crime related Master's programmes at UCL to participate. Out of them, two failed to complete the initial registration form (a self-administered survey about their demographic information, language, crime modelling experience, and crime prevention related experience) on time and one did not consent for their data to be used in the study. In addition, three other participants were excluded from the rest of studies as two did not meet the eligibility requirements and one was a statistical outlier.

Table 5.1: Factors considered and controlled in the goals effect experiment

factor	included in the experiment	changes during the experiment	measured	how it is measured	condition
age	yes	no	yes	It is asked from the volunteers and controlled in the registration step.	Considering the ethical concerns of the experiment (as there will be an online-stalking crime event in the experiments' materials), all the participants should be at least 18 years old.
sex	yes	no	yes	It is asked from the volunteers and controlled in the registration step.	The participants can have any gender.
degree	yes	no	yes	It is asked from the volunteers and controlled in the registration step.	All the participants should be a current/graduated postgraduate student.
academic background	yes	no	yes	It is asked from the volunteers and controlled in the registration step.	All the participants should be a current/graduated postgraduate student, in a related discipline, e.g., crime science or criminology.
language	yes	no	yes	It is asked from the volunteers and controlled in the registration step.	All the participants should be a native speaker or a second language speaker who has obtained a degree from an English institute or a current student in an English language institute.
high level knowledge of crime prevention	yes	no	yes	It is asked from the volunteers and controlled in the registration step.	All the participants should have a high level understanding of crime prevention measures.
crime scripting background	yes	yes	yes	It is asked from the volunteers and controlled in the registration step.	All the participants will be trained about crime script concept and how to write a crime script.
knowledge of SCP	yes	yes	yes	It is asked from the volunteers and controlled in the registration step.	The participants can be familiar with SCP but should not have a deep knowledge about SCP techniques. Some of the participants will be trained about required SCP techniques for the experiment.
amount of time for the experiment	yes	yes, for some	yes	The experiment time is measured and controlled.	All the participants have a same time limit for writing the script and their given training.
tools	yes	no	yes	NA	All the participants use a same tool for writing their scripts.
data	yes	no	yes	NA	All the participants are provided same data about the crime event.
environment	yes	no	yes	NA	All the participants use a same room to complete the experiment.
procedure	yes	no	yes	NA	Participants within each group follow a same procedure. However, the groups may have different tasks.
learning	yes	no	yes	NA	Participants within each group are provided a same learning material. However, different groups may have provided different learning materials.
crime scripting method	yes	no	yes	NA	Scripters are not told about any specific crime scripting method, so they can use any scripting method that they like, which, here, is being considered as an intuitive method.

From the remaining 127 selected volunteers, 124 (63% female, μ = 24 y.o., std= 5.19) completed the given crime scripting task (described below).

The participants were randomly assigned to one of three scripter groups ($SG_{G_{atm}}$ or ATM group; $SG_{G_{cctv}}$ or CCTV group; and $SG_{\emptyset}$ or $SG_{control-group}$ or control group). This was done by generating for each participant a random number. The participants were then sorted based on that number and sorted list was divided into three nearly equal groups (43, 42, and 42 for the 127 selected volunteers). Those scripter groups were then randomly sorted (in the same way as described for the participants) and each group was then assigned to the $SG_{\emptyset}$, $SG_{G_{atm}}$, and $SG_{G_{cctv}}$ groups respectively. More specifically, the first group (first 43) was assigned as the control group, the next group (next 42) as the ATM group, and the last group (last 42) as the CCTV group.

As shown in Tables 5.2 and 5.3, the demographics of the final 124 participants indicate that there are no significant difference between the three groups. The participants were all similarly fluent in English and had a similar understanding of crime scripting and crime prevention (i.e. because they were doing a course related to this field). The groups were also similar in terms of age and gender combinations.

Table 5.2: Statistical test for groups' variable

Variable	P-value (KW test)	Significance (alpha = 0.05)
Age	0.48	not significant
Sex	0.93	not significant
Language	0.9	not significant
Crime scripting/crime modelling	0.76	not significant
SCP/Crime prevention experience	0.14	not significant

Randomisation checks were run to test whether the assigned groups were similar in terms of the following characteristics: age, gender, language, crime modelling experience, and crime prevention related experience. These were done by com-

paring the mean value for the mentioned variables with other possible alternatives for them and also between the groups. For example, the randomisation check for the variable age was done following these steps: i) simulating the random assignment of the selected volunteers to the groups, ii) repeating the simulated process for 10000 times, iii) calculating and saving the average age of the assigned groups in each repeat. The minimum and maximum averages for those groups were 23 and 28, respectively— the lowest possible minimum was 21, and the highest possible maximum was 31. The results suggest, the mean age of the scripter groups ($\sim$25) were almost always in the middle of this range which shows they had an acceptable mean value. In addition, the age mean value for the three groups were calculated and compared, they were very close, which shows all three groups had almost the same combination of participants in terms of age.

Table 5.3: Demographic characteristics for participants

	Control group	Experimental group 1	Experimental group 2
Number of participants	43	42	39
Age, min	20	20	21
Age, max	44	51	42
Age, mean	25.06	24.9	25.18
Age, SD	6.07	5.16	4.2
Gender-male	40%	36%	33%
Gender-female	60%	64%	64%
Gender-prefer not to say	0	0	3%
Language, native English speaker	61%	50%	51%
Language, a second language speaker with a university degree from an English language institution	33%	48%	49%
Language, a second language speaker and studying in an English language institution	39%	50%	49%
Crime modelling experience, not familiar	51%	57%	53%
Crime modelling experience, looked at some	49%	43%	47%
Crime modelling experience, created some	0	0	0
Crime modelling experience, used them to propose SCP	0	0	0
Crime prevention experience, not familiar	0	0	0
Crime prevention experience, know the five principles of SCP	35%	32%	36%
Crime prevention experience, have studied several cases of SCP, understand well	65%	68%	64%

Materials

Training materials

A *crime scripting training video* was made available online to the participants—on UCL's online learning management system (Moodle). The video was to complement and refresh participants' crime scripting skills, covering an *introduction*, *using crime scripts* in identifying SCP measures, detailing *crime scripts' components* (e.g., actors, actions, places, resources, skills, knowledge, etc.), some *examples* for the introduced concepts, and an instruction on *how to write a brand new crime script*.

Scripting materials

The crime event to be scripted was a *bank card theft* which was shown using a 78-second video footage representing the incident happened at a Natwest ATM on the 14^{th} December 2015. There was no meaningful sound on the video and the scripters wrote their scripts based on visual information from a *single-scene single-shot* footage (and their own prior knowledge and experience e.g., bank card theft crime events). The video is available online on this URL: `https://www.youtube.com/watch?time_continue=1&v=bAOY_XAzpag`. As shown in Figure 5.2, the image quality is such that the main elements of the scene could be identified within the allotted time. The video was presumably recorded by a stationary colour CCTV camera located inside the ATM area at a shop/shopping centre's entrance, near the ceiling and pointing toward the ATM area. The most visible el-

ements in the footage are two ATMs, the entrance, the corner table, the victim, the three offenders, five by-passers, and some people inside the shop. The video was uploaded and played at $\times 1$ speed.

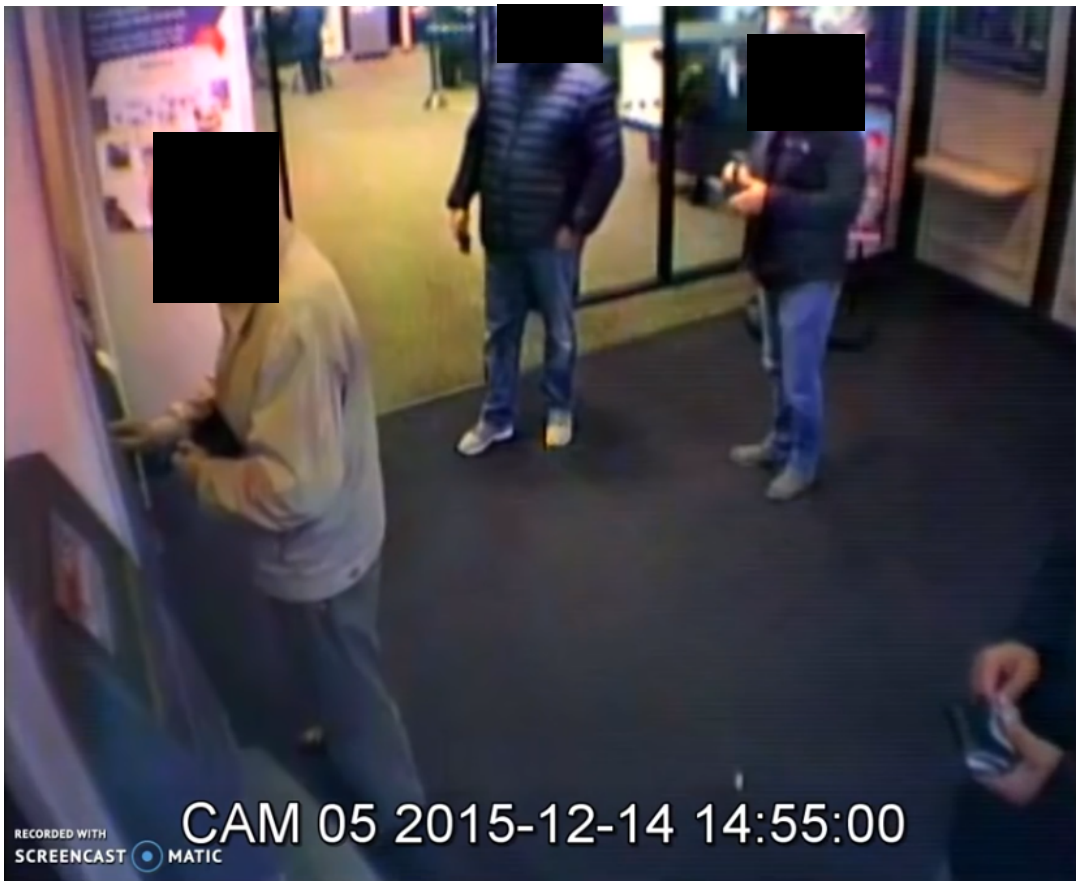

Figure 5.2: Image from the video footage— the three offenders (right) disturb the victim (left) and steal his bank card and its pin.

Protocol

Participants recruitment

This started by emailing an invitation (to be involved in the study) to all potential volunteers. This email provided a brief description of the study's objectives and structure and its purpose.

An initial profile of participants including some basic personal details of them was collected— e.g., age, gender, and email address. The latter was the only mandatory field, which was used as the volunteers' unique identification in the experiment. Age and gender were used to provide some statistics about the groups' combinations, e.g., for the randomisation checks. Next, participants filled a questionnaire about their education, language, experience of crime scripting and crime prevention which was used for shortlisting. A consent form was also sent to be completed. The questionnaire was designed based on the factors listed in Table 5.1 and a copy is available in appendix A.

Ethical points

Because some of the experiments' materials (for example *bank-card-theft* crime) may not be ethically suitable for those under 18, participants were required to be 18 years or over. In terms of the user's information/personal data, there were no link between the collected data and the participants' identity after *data collection* and all the collected data were kept and analysed anonymously. The participants' consent about using their script in this research was requested.

Training

Participants were asked to review the training materials by a given deadline. This was to refresh their crime scripting knowledge and to prepare them for writing a script.

Crime scripting test

At the end of the training stage, the volunteers completed an online *crime scripting test* which was available to them online at `Surveymonkey.com`. The test comprised of different questions and was intended to inspect whether volunteers had gained or had adequate knowledge and skills to take part in the next steps of the experiment. That is with respect to the materials that were covered in the training video. A copy of the training video slides and the taken test can be found in appendices B and C, respectively. To pass the test (and show they had enough knowledge), volunteers were required to correctly answer 70% or more of the test's questions.

Writing script

The participants visited the provided online page to write a crime script for the given crime event (represented in the video embedded in the page), following the given instruction and the description of the *crime-script-to-be* application's goal. The latter was the only difference in the materials given to the groups. All the other factors were identical across the groups, including the time of the experiment, the experiment environment, the crime scripting instruction, and the data representing the crime event. The participants had to write their scripts in the allocated time. An example of a scripting task is shown in Figure 5.3. The three given tasks are shown in Table 5.4 and full participants' given tasks for this experiment can be found in appendix D.

Over the last few years, a number of crimes have happened at UK bank branches. Using the same modus operandi, offenders have committed the same crime against a large number of victims.

A consortium of banks have consulted security experts about it, and they concluded that the most promising solution to the problem would be to **redesign the Automated Teller Machines** (ATMs) **to make it more difficult for offenders to commit the crime.**

ATM Design and Security Risks

Your company has been contracted to redesign ATMs, so it ismore difficult for offenders to exploit their vulnerabilities. You have been tasked to draw a list of recommendations for the design of the new ATMs.
To perform your task:

1. **Watch the video below (you can pause, replay, and go backward/forward as many times as you need). It represents a crime captured by a CCTV system at a Natwest branch (~1 minute).**
2. **Identify specific vulnerabilities in the existing Automated Teller Machines (ATMs) that were exploited by offenders,**
3. **Come up with ideas for the design of ATMs so offenders would not be able to commit this crime**
4. **Then, write your suggestions in the box below:**

Figure 5.3: A part of the *scripting* task for $SG_{G_{atm}}$

5.2.2 Coding

This section explains how the information within the collected scripts are coded and prepared for testing the hypothesis. The coding process started by giving a unique ID to each script— e.g., $CS_5SG_{G_1}$ that indicates the crime script number 5 written by a scripter in SG_{G_1}. Then the information available in all the collected crime scripts are classified and listed in a *classification table* following the designed classification approach that was explained in chapter 4. The result of this process is a

Table 5.4: Bank card theft experiment— groups and their given application

SG_{G_1} or $SG_{G_{atm}}$	Over the last few years, a number of crimes have happened at UK bank branches. Using the same modus operandi, offenders have committed the same crime against a large number of victims. A consortium of banks have consulted security experts about it, and they concluded that the most promising solution to the problem would be to redesign the Automated Teller Machines (ATMs) to make it more difficult for offenders to commit the crime. Your company has been contracted to redesign ATMs, so it is more difficult for offenders to exploit their vulnerabilities. It has been tasked to draw a list of recommendations for the design of the new ATMs. Your task is to write a crime script that will be used for this process. Now, watch the video and write a crime script for the shown crime event.
SG_{G_2} or $SG_{G_{cctv}}$	Over the last few years, a number of crimes have happened at UK bank branches. Using the same modus operandi, offenders have committed the same crime against a large number of victims. A consortium of banks have consulted security experts about it, and they concluded that the most promising solution to the problem would be to redesign the Surveillance system (CCTV cameras, video analytic software) to make it more risky for offenders to commit the crime. Your company has been contracted to develop a system to detect and identify repeat offenders. it has been tasked to draw a list of recommendations for the design of the new Surveillance system (CCTV cameras, video analytic software) and its deployment. Your task is to write a crime script that will be used for this process. Now, watch the video and write a crime script for the shown crime event.
$SG_{G_\emptyset}$ or $SG_{G_{control-group}}$	Over the last few years, a number of crimes have happened at UK bank branches. Using the same modus operandi, offenders have committed the same crime against a large number of victims. Your task is to write a crime script that describes the crime event on the video. Now, watch the video and write a crime script for the shown crime event.

classification table that represents all the information in the collected scripts. Within this table, each row or class is unique and represents a single step of the crime process. Table 5.5 shows an example of the classification table. In this table, each row is a step in the crime event. Each column represents a particular participant's script and the intersection of each column and row indicates whether a specific step was included in a specific participant's script.

Table 5.5: An example of the classification table

crime script steps	$CS_1SG_{G_1}$	$CS_2SG_{G_1}$
step number 1	1	0
step number 2	1	1

CS_iSGG_j is crime script number i (written by scripter number i) from scripter group j (were given G_j)

The adapted classification approach

The classification system that was explained in section 4.2.3 is used here for classifying the information within the collected scripts.

The first column of the result classification table is called *aggregated script*, which contains the information that was written across all of the collected scripts.

Identifying related steps

Testing the hypothesis is accomplished using the variables introduced in section 5.2, which are:

- *IV* (independent variable): the scripters knowledge about the application's goal, which is given to each scripter. For example, in Table 5.5 for the component in the conjunction of row *step number 1* and column $CS_1SG_{G_1}$ (that is the vector for crime script number 1, written by a scripter from intervention group SG_1 who was given goal 1), *IV* is 'To improve ATM design'.

- *DV* (dependent variable): the presence of a step in a crime script when that step is relevant to a specific goal. *DV* is calculated by applying logical *AND* on two Boolean values that are:

  - $DV1$: the presence of a step in a crime script. This can be extracted from the classification table. For example, for *step number 1* and script $CS_1SG_{G_1}$ in Table 5.5, $DV1$ is 1 as the corresponding cell in the crime script's vector is 1.

  - $DV2$: the existence of a relationship between a crime script's step and a specific goal. In this research, the values for $DV2$ come from a *relationship table* that is generated based on experts' opinion.

A step is judged to be related to a goal if that step directs security analysts toward some crime prevention measures that contribute in satisfying the given goal. For example, let's consider St_1: 'Offender makes unauthorised access to the building' as a crime script step and G_1: 'To prevent unauthorised access to the buildings' as an application goal. Here, St_1 shows a problem/vulnerability with *the building's access control process/design* and directs the analysts toward some interventions in the building [access control] design to improve this problem; e.g., applying some changes in the building settings to prevent unauthorised access and make the access to the building more difficult to offenders. So, St_1 can be considered to be related to G_1. The process of generating this table is explained next.

Constructing relationship table

The *relationship table* suggests whether there is a relationship between scripts' steps and scripting goals— the values for $DV2$. This table is constructed based on the opinions of several experts opinion as the measure that suggests the existence of a relationship between scripts' steps and goals. This process was followed as the experts should have a deep knowledge and understanding about crime scripts, crime scripting, and using scripts in identifying situational prevention measures. Three experts participate in this stage, following two steps:

- Filling *single-goal relationship tables*: experts are given two *relationship ta-*

bles, each for one of the goals, to express whether they perceive a relationship between each script's step and goals. They completed the tables independently following their given instruction, as shown in Figure 5.4. Each table has two columns, first column is the aggregated script that comes directly from the classification table. Second column is a Boolean value that shows the existence of a relationship between each step and a goal, as perceived by the experts. The tables were given to the experts in a random order.

- Generating final relationship table by merging the experts' tables: considering two application goals, there will be two *types of crime script step* in the final relationship table's sheets (each sheet is for a goal):

  - $St_{R_{G_i}}$: steps related to G_i, and

  - $\overline{St_{R_{G_i}}}$: steps not related to G_i.

  The hypothesis concerns only about the steps related to a given goal, e.g., $St_{R_{G_1}}$, not $St_{R_{G_1\overline{G_2}}}$ or $St_{R_{\overline{G_1}}}$. So, to test the hypothesis, this research just focuses on $St_{R_{G_i}}$.

  The final relationship table is made upon expert's relationship tables. This has three columns: the first column is the aggregated script and the next two columns contain the vectors that show the existence of a relationship between the aggregated script steps and the goals— as perceived by the experts. These two columns are calculated in the same way following the experts majority

point of view. So, the value of a cell e.g., A is 1 if more than one expert have put 1 in A's corresponding cell in their first table, otherwise A is 0.

Inter-rater reliability: once the first draft for the relationship table was created, the experts discussed their answers and the final values of the table were decided.

Table 5.6 shows an example of the relationship table.

Table 5.6: An example of the final relationship table

script steps	$St_{R_{G_1}}$	$St_{R_{G_2}}$
St_1	0	0
St_2	0	0
St_3	0	1
St_4	1	0

St_i represents step number i in the aggregated script

$St_{R_{G_j}}$ is set of steps related to G_j

$St_i St_{R_{G_j}}$ is step number i in $St_{R_{G_j}}$, which has a Boolean value, etc.

$St_i St_{R_{G_j}}$ is calculated based on experts' answers in their *relationship tables*

$$St_i St_{R_{G_j}} = (Ex_1 St_i St_{R_{G_1}} \odot (Ex_2 St_i St_{R_{G_1}} + Ex_3 St_i St_{R_{G_1}}) + EX_2 St_i St_{R_{G_1}} \odot (EX_1 St_i St_{R_{G_1}} + EX_3 St_i St_{R_{G_1}}))$$

where

$Ex_k St_i St_{R_{G_j}}$ is the expert k's answer about the relationship between St_i and G_j, etc.
and
$\odot$ and $+$ are the Boolean operators *AND* and *OR*, respectively.

5.2.3 Analysis

The hypothesis suggests the amount of information related to a goal should be greater when scripters are aware/given/told about that goal.

What is expected?

The three groups of scripts were collected in scripting stage are SG_{G_1}, SG_{G_2}, and $SG_{G_\emptyset}$. Considering the hypothesis, the three script groups, and two types of script steps ($St_{R_{G_1}}$ and $St_{R_{G_2}}$ that are the main concern on this testing), four meaningful

Dear Colleague

Thank you so much for accepting to help me with crime scripting experiment.

The experiment

My crime scripting experiment examines how informing crime scripters about **crime scripts application goals** and **situational crime prevention techniques affect scripts content,** i.e. script's steps.
For this, I need to compare the crime script steps identified by the participants (under each experimental condition) to a list of the crime script steps that should be identified (by experts, i.e. by yourself). For this task you just need to select the crime steps based on your judgement of the possible steps in terms of the goals.

Your task

Please fill column C (C2:C50) and D (D2:D49) on the next two sheets. It approximately would take less than an hour.
Column C: The value for column C is a boolean value to be selected from the provided drop-down (blank cell will be judgement as a "NO")
You will select "Yes" for this column, if you perceive a relationship between the script step that is mentioned in column C of each row with the goal that is mentioned in cell C1 of each sheet.
Column D: The value for column D is a possible intervention that shows (let's say in row [i]) how B[i] is related to C1

What does it mean when we say " there exist a relationship between a script's step and a goal"?

A step is related to a goal, if that step directs security analysts toward some crime prevention measures that contribute in satisfying the given goal.

For example:
Let's consider crime script step S1: **Offender makes unauthorised access to the building**
And crime scripting goal G1: **To improve the building security design**

Here, one can imply from S1 that there exist a problem/vulnerability with the building's access control process/design and conclude some interventions should be made in the building [access control] design to improve the problem(s), e.g., applying some changes in the building settings to prevent unauthorised access by making the access to the building more
So S1 can be considered to be related to G1.

For this example, your answer can be:
Column C: Yes
Column D: to improve the access control process

Please fill the below and after finishing, email the excel sheet back to my email (h.dehghanniri.12@ucl.ac.uk)

Your name

Your experience with crime scripting

Date

Many thanks for your cooperation
Hashem Dehghanniri

Figure 5.4: The expert's instruction for filling the *relationship table*

results could be expected:

- The average number of steps related to G_1 in SG_{G_1} to be greater than the average number of steps related to G_1 in
  - SG_{G_2} or
  - $SG_{G_\emptyset}$.
- The average number of steps related to G_2 in SG_{G_2} to be greater than the average number of steps related to G_2 in
  - SG_{G_1} or
  - $SG_{G_\emptyset}$.

these expectations are summarised in Table 5.7.

Table 5.7: Four expected results based on this chapter's hypothesis

	SG_{G_1}	SG_{G_2}
SG_{G_1}	NA	$\bar{x}(St_{R_{G_2}}\|SG_{G_2}) > \bar{x}(St_{R_{G_2}}\|SG_{G_1})$
SG_{G_2}	$\bar{x}(St_{R_{G_1}}\|SG_{G_1}) > \bar{x}(St_{R_{G_1}}\|SG_{G_2})$	NA
$SG_{G_\emptyset}$	$\bar{x}(St_{R_{G_1}}\|SG_{G_1}) > \bar{x}(St_{R_{G_1}}\|SG_{G_\emptyset})$	$\bar{x}(St_{R_{G_2}}\|SG_{G_2}) > \bar{x}(St_{R_{G_2}}\|SG_{G_\emptyset})$

$\bar{x}(St_{R_{G_i}}|SG_{G_j})$ is the mean/average of all the steps related to G_i in the scripts that were written by SG_{G_i}

Statistical analysis

The above expectations are assessed by statistically comparing the mean values of related steps to different goals in various groups— as shown in Table 5.7.

Statistical tests: the hypothesis can be tested by comparing the mean of the number of steps related to a goal in an intervention group with the number of steps related to

the same goal in the other two groups who received different treatments. This is by comparing the three means that represent the effects of three different values for a same independent variable on a same dependent variable— comparing differences between the means of more than one group. This research uses regression for comparing the differences between the means of the three groups and tests the fit of the regression model to its use with an ANOVA (the F-test) (Field 2013). Here, there were different levels/values for a single independent variable and one dependent variable. As there is only one factor that is different between the groups, one-way ANOVA is used for the test.

Normality test: ANOVA assumes that the data are (approximately) normally distributed. If the measurement variable is not, there is a greater chance of a false positive result in analysis of the data. To assess this assumption, the skewness and kurtosis z-values were assessed whereby if the values are between -1.96 and +1.96 the data is assumed to be normally distributed.

Alternative statistical tests: if any of skewness and kurtosis z-values resulted from normality test is not in the range of -1.96 to +1.96, then the data was assumed to be not normally distributed. In this case (and as later found, see later), a non-parametric statistical test should be conducted instead of ANOVA for testing the hypothesis. For this, the current research uses the Kruskal-Wallis (KW) test, which is non-parametric equivalent of ANOVA. KW test is for comparing two or more independent samples of equal or different sample sizes.

Here, as there are more than two groups, if KW test suggests an overall statistically significant difference in group means, it suggests there is an overall difference between the three groups. The KW test however does not indicate which specific groups differed. To understand this the difference between each pair of groups is compared separately using the Mann-Whitney test (MW). However as this will result in multiple comparisons for the same hypothesis which increases the chances of a false positive (i.e. multiplicity), the p-values are adjusted using the Bonferroni correction. More specifically, for each hypothesis the p-values are multiplied by 3 (the number of possible combination of group pairs) before interpreting the results.

5.3 Results

5.3.1 The collected scripts

This section reports the analysis of the collected scripts and compares them within and between different groups.

All the 124 scripts have been coded and merged, which resulted to an aggregated script with 99 steps as is shown in Table 5.8.

Table 5.8: The aggregated crime script for bank card theft experiment

Step no	Crime script step
1	Offender decides to steal money/defraud someone
2	Offenders collect required info e.g. about ATMs, possible ATM location, time, victim's features
3	Offenders plan the crime process e.g. selecting location, time, potential target, etc.

4	Offenders produce/acquire the materials needed e.g. suitable bank cards, or note (to drop and distract the victim)
5	Offenders team up
6	Offenders go to the location
7	Offenders wait for opportunity (right victim, quiet area, etc.)
8	Victim walks to the ATM #1 to withdraw cash
9	CCTV observes the victim
10	Victim starts to use ATM #1 to withdraw cash
11	ATM #1 shows the interactive menu to the user
12	Victim focuses on ATM #1 and proceed with his order
13	Victim finishes using ATM #1 and waits for his money and card
14	Bypasser #1 (a man with black jacket) goes into the store through the ATM area
15	Bypasser #2 (a lady with a walker) goes into store
16	Offender #1 (with a flat cap hat) goes to the ATM #2 (left side of the victim)
17	CCTV observes offender #1
18	Offender #1 stands somewhere to see the victim's bank card-type, pin , and the ATM's screen
19	Offender #1 watches and memories victims pin number
20	Offender #1 pretends to use the ATM #2
21	Offender #1 takes a device from his pocket e.g., phone
22	Offender #1 direct the device toward the victim
23	Offender #1 inserts device in ATM #2
24	Offender #1 takes picture or video using his phone while the victim is entering his information
25	CCTV observes offender #2
26	Offender #2 doesn't notice the CCTV
27	Offender #2 (bald one) queues behind and pretends to wait for ATM #1
28	Offender #2 monitors victim's activities and waits for the right time to swap the cards
29	Offender #2 watches victim e.g., his pin/card type
30	Offender #3 (with a pie hat and glasses) stands behind Offender #1 (ATM #2 queue left side of the victim) pretends to be waiting for ATM #2 and waits for the right time to complete his job (distracting the victim)
31	Offender #3 has his wallet and a note (to be dropped) ready in his hand
32	Offenders watches victim's activities e.g. entering pin
33	Offender #1 looks around and checks the situation e.g. who is coming in
34	Offender #2 looks around and checks the situation e.g. who is coming in
35	Offender #3 looks around and checks the situation e.g. who is coming in

36	Offenders try to keep both ATMs busy; so no-one else is nearby except for themselves and their victim
37	Offender #1 signals that the pin has been memorised (by touching his head)
38	Offender #1 pretends he has finished with ATM #2 and walks away from ATM #2
39	Offender #1 goes (leaves ATM #2) and stands close to offender #2 and behind the victim
40	Bypasser #3 (a lady with blue jacket) goes out
41	there are few clients around entering and leaving the store
42	Bypasser #4 (a lady with red jacket) goes in
43	Bypasser #5 (a lady with pink jacket) goes in
44	Staff member walks toward ATM area
45	Offender #1 quietly talks with the Offender #2 (e.g., about the victim's pin/type of card)
46	Offender #3 make eye contact with his colleagues
47	Offenders make eye contact
48	Offender #1 goes to the store/lobby to control the coming bypassers
49	Offender #1 intercept the staff member
50	Offender #1 leaves the CCTV area
51	Offender #3 keeps watching victims activities on ATM #2
52	Offenders monitors victims action/focusing on him
53	Offenders wait for victim to finish with ATM #1 e.g., for the card to be ejected by the ATM
54	Victim finishes with ATM #1 and waits for his receipt, card, and cash from ATM #1
55	ATM #1 prints a receipt
56	Victim takes the receipt and puts it in his pocket
57	Offender #2 comes closer to ATM#1 behind victim (to be seen by the victim) and distracts him
58	Victim notices offender #2 waiting behind him and looks at him
59	Offender #2 signals to the victim that he is waiting to use the ATM #1 by showing his card to him
60	Offender #2 observes victim's banking information
61	Victim looks back to the ATM#1 screen
62	Victim opens his wallet
63	Offenders wait for the victim's card to be ejected
64	Offender3 intentionally drops something on the floor close to Victim (between ATM #1 and #2) to distract the victim
65	CCTV does not capture what was dropped by offender #3
66	Offender #3 distracts the victim using ATM #1 by telling him that he has dropped something
67	Offender #3 leaves the scene
68	Offender #3 leaves CCTV area

69	Victim leaves ATM#1 unattended and goes to pick up what's been dropped
70	Offender #2 prepares a card similar to the victim's card to replace with victim's card
71	ATM #1 ejects the user(victim)'s bank card
72	Offender #2 quickly goes to ATM #1 and swaps his bank card with a dummy one
73	ATM#1 allows the actor (offender #2) to take the card from the slot
74	Offender #2 steps back and pretends he is still waiting
75	Victim picks up what was dropped (the note)
76	Victim puts the note on ATM #1
77	Victim (gets up) backs to ATM #1 to finish his transaction
78	Victim takes the (dummy) card on ATM #1 and doesn't notice that it's not his card
79	victim uses fake card unwittingly
80	Offender #1 walks out of the ATM area and leaves the scene
81	Offender leaves the scene
82	ATM#1 ejects the money (notes)
83	Offender #2 now has the victim's bank card and its pin number
84	Offender #2 goes to ATM #2 and pretends he uses ATM #2
85	Victim takes his money from ATM #1 and finishes using ATM #1
86	Victim walks away from ATM #1 to the corner table of ATM area (e.g. to organise his items)
87	Offender #2 pretends that his transaction at ATM #2 completed
88	Offender #2 removes money from his wallet
89	Offender #2 puts stolen card away
90	Offender #2 actions on ATM #2 is not clear on CCTV footage
91	Offender #2 leaves the scene with the victim's card
92	Offender #2 leaves the scene without the card
93	Offender #2 leaves the victim's card in ATM
94	Offender #2 leaves the CCTV view
95	Offenders leave the area
96	Offenders meet after the event
97	Offenders wait to appear less suspicious
98	Victim walks behind the offender
99	Victim is unable to use ATM

Table 5.9 shows some general information about the collected scripts; as can be seen in Table 5.8:

Table 5.9: Descriptive information of the collected crime scripts

	ATM group	CCTV group	Control group	Total
Number of collected scripts	42	39	43	124
Total number of steps of scripts	827	749	826	2402
Average number of steps in each script	19.69	19.21	19.21	—
Number of steps in the aggregated script	78	62	64	—
Number of steps of the longest script	32	35	33	—
Number of steps of the shortest script	9	8	8	—

After quality checks and removing outliers, 124 scripts were collected and analysed including 42 in the ATM group, 39 in the CCTV group, and 43 in the control group.

The collected scripts were merged using the method that was explained in chapter 4, which yielded an aggregated script with 99 different steps. Scripts in the ATM group were mapped to 78 steps of the aggregated script, which was higher than the other two groups: 64 and 62 for $SG_{G_\emptyset}$, and $SG_{G_{cctv}}$, respectively.

The longest script was mapped onto 35 steps of the aggregated script, which was in $SG_{G_{cctv}}$ and the two shortest ones which were mapped onto 8 steps were in $SG_{G_{cctv}}$ and $SG_{G_\emptyset}$.

The collected scripts had 2402 steps in total and the average number of steps in each script was 19.37. The numbers for SG_{atm} (827 and 19.69) were higher than for the other two groups: (749 and 19.21) for $SG_{G_{cctv}}$, and (826 and 19.21) for $SG_{G_\emptyset}$.

There was no step in the aggregated scrip that could be found in all 124 scripts; however, one step in the aggregated script was shared in all the scripts in $SG_{G_{atm}}$, and two steps were shared in all the scripts in $SG_{G_\emptyset}$.

5.3.2 The collected scripts' steps and goals

This section describes the analysis of the collected scripts' steps considering their relation with the goals (G_{atm} and G_{cctv}). Table 5.10 shows the number of steps that are identified to be related to different goal combinations, as determined by the experts. As shown in this table, out of the 99 steps in the aggregated script, 53 were recognised to be related to G_{atm}, 34 to G_{cctv}, 40 to $G_{atm}\overline{G_{cctv}}$, 21 to $\overline{G_{atm}}G_{cctv}$, 13 to $G_{atm}G_{cctv}$, and 25 to $\overline{G_{atm}G_{cctv}}$. The experts in general agreed about this though the highest agreement was about the steps related to $\overline{G_{atm}}G_{cctv}$ (83%) and the lowest was about the steps related to $\overline{G_{atm}G_{cctv}}$ (73%).

Table 5.10: Number of steps that are identified to be related to different goals combinations and their relevant experts' agreement rate

Goal combination	Number of the steps identified to be related to the goal combination	Agreement rate on steps identified to be related to the goal combination	Agreement rate on steps identified to be unrelated to the goal combination
G_{atm}	53 (54%)	74%	80%
G_{cctv}	34 (34%)	80%	70%
$G_{atm}\overline{G_{cctv}}$	40 (40%)	72%	77%
$\overline{G_{atm}}G_{cctv}$	21 (21%)	83%	73%
$G_{atm}G_{cctv}$	13 (13%)	76%	75%
$\overline{G_{atm}G_{cctv}}$	25 (54%)	73%	76%
Average	31 (31%)	76%	75%

Table 5.11 shows the experts' agreement rate of the relationship between the goals and each of the aggregated script's steps.

Table 5.11: Experts' agreement rate of the relationship between the goals and individual steps in the aggregated script

Step no in the aggregated script	Related to ATM	Aggregated rate on ATM related steps	Related to CCTV	Aggregated rate on CCTV related steps
1	Yes	67% agreed to be related	No	100% agreed to be unrelated
2	Yes	67% agreed to be related	Yes	67% agreed to be related
3	Yes	67% agreed to be related	Yes	67% agreed to be related
4	Yes	67% agreed to be related	No	100% agreed to be unrelated
5	Yes	67% agreed to be related	No	100% agreed to be unrelated
6	No	67% agreed to be unrelated	No	100% agreed to be unrelated
7	Yes	67% agreed to be related	No	67% agreed to be unrelated
8	Yes	67% agreed to be related	No	67% agreed to be unrelated
9	No	67% agreed to be unrelated	Yes	100% agreed to be related
10	No	67% agreed to be unrelated	No	67% agreed to be unrelated
11	Yes	67% agreed to be related	Yes	67% agreed to be related
12	Yes	67% agreed to be related	No	100% agreed to be unrelated
13	Yes	100% agreed to be related	No	67% agreed to be unrelated
14	No	67% agreed to be unrelated	Yes	67% agreed to be related
15	No	67% agreed to be unrelated	Yes	67% agreed to be related
16	Yes	100% agreed to be related	No	67% agreed to be unrelated
17	No	100% agreed to be unrelated	Yes	100% agreed to be related
18	Yes	100% agreed to be related	Yes	67% agreed to be related
19	Yes	100% agreed to be related	Yes	67% agreed to be related
20	No	67% agreed to be unrelated	Yes	67% agreed to be related
21	No	100% agreed to be unrelated	No	67% agreed to be unrelated
22	Yes	67% agreed to be related	No	67% agreed to be unrelated
23	No	67% agreed to be unrelated	No	67% agreed to be unrelated
24	No	67% agreed to be unrelated	No	67% agreed to be unrelated
25	No	100% agreed to be unrelated	Yes	100% agreed to be related
26	Yes	67% agreed to be related	Yes	100% agreed to be related
27	No	67% agreed to be unrelated	No	67% agreed to be unrelated

28	Yes	100% agreed to be related	No	67% agreed to be unrelated
29	Yes	100% agreed to be related	No	67% agreed to be unrelated
30	Yes	100% agreed to be related	No	67% agreed to be unrelated
31	No	100% agreed to be unrelated	Yes	67% agreed to be related
32	Yes	100% agreed to be related	No	67% agreed to be unrelated
33	No	67% agreed to be unrelated	Yes	100% agreed to be related
34	No	67% agreed to be unrelated	Yes	100% agreed to be related
35	No	67% agreed to be unrelated	Yes	100% agreed to be related
36	Yes	67% agreed to be related	No	67% agreed to be unrelated
37	No	100% agreed to be unrelated	Yes	67% agreed to be related
38	No	100% agreed to be unrelated	Yes	100% agreed to be related
39	No	67% agreed to be unrelated	No	67% agreed to be unrelated
40	No	100% agreed to be unrelated	Yes	67% agreed to be related
41	Yes	67% agreed to be related	No	67% agreed to be unrelated
42	No	100% agreed to be unrelated	Yes	67% agreed to be related
43	No	100% agreed to be unrelated	Yes	67% agreed to be related
44	Yes	67% agreed to be related	No	67% agreed to be unrelated
45	No	67% agreed to be unrelated	No	67% agreed to be unrelated
46	No	100% agreed to be unrelated	No	67% agreed to be unrelated
47	No	100% agreed to be unrelated	Yes	67% agreed to be related
48	No	67% agreed to be unrelated	No	67% agreed to be unrelated
49	Yes	67% agreed to be related	No	67% agreed to be unrelated
50	Yes	67% agreed to be related	Yes	100% agreed to be related
51	Yes	100% agreed to be related	No	67% agreed to be unrelated
52	Yes	67% agreed to be related	No	67% agreed to be unrelated
53	Yes	100% agreed to be related	Yes	67% agreed to be related
54	Yes	67% agreed to be related	No	67% agreed to be unrelated
55	Yes	67% agreed to be related	No	67% agreed to be unrelated
56	No	100% agreed to be unrelated	No	67% agreed to be unrelated
57	Yes	100% agreed to be related	No	67% agreed to be unrelated
58	Yes	67% agreed to be related	Yes	67% agreed to be related
59	No	67% agreed to be unrelated	No	67% agreed to be unrelated
60	Yes	67% agreed to be related	Yes	67% agreed to be related

61	Yes	67% agreed to be related	No	67% agreed to be unrelated
62	No	100% agreed to be unrelated	Yes	67% agreed to be related
63	Yes	67% agreed to be related	Yes	67% agreed to be related
64	No	67% agreed to be unrelated	No	67% agreed to be unrelated
65	No	67% agreed to be unrelated	Yes	100% agreed to be related
66	Yes	67% agreed to be related	No	67% agreed to be unrelated
67	No	100% agreed to be unrelated	No	67% agreed to be unrelated
68	Yes	67% agreed to be related	Yes	100% agreed to be related
69	Yes	67% agreed to be related	No	67% agreed to be unrelated
70	No	67% agreed to be unrelated	No	67% agreed to be unrelated
71	Yes	67% agreed to be related	No	67% agreed to be unrelated
72	Yes	67% agreed to be related	No	67% agreed to be unrelated
73	Yes	67% agreed to be related	No	67% agreed to be unrelated
74	No	100% agreed to be unrelated	No	67% agreed to be unrelated
75	Yes	67% agreed to be related	No	67% agreed to be unrelated
76	No	67% agreed to be unrelated	Yes	67% agreed to be related
77	No	67% agreed to be unrelated	No	67% agreed to be unrelated
78	Yes	67% agreed to be related	No	67% agreed to be unrelated
79	No	67% agreed to be unrelated	No	67% agreed to be unrelated
80	No	67% agreed to be unrelated	Yes	100% agreed to be related
81	No	100% agreed to be unrelated	Yes	100% agreed to be unrelated
82	Yes	67% agreed to be related	No	67% agreed to be unrelated
83	Yes	67% agreed to be related	No	67% agreed to be unrelated
84	No	67% agreed to be unrelated	No	67% agreed to be unrelated
85	Yes	67% agreed to be related	No	67% agreed to be unrelated
86	No	67% agreed to be unrelated	No	67% agreed to be unrelated
87	Yes	67% agreed to be related	No	67% agreed to be unrelated
88	No	100% agreed to be unrelated	No	67% agreed to be unrelated
89	Yes	67% agreed to be related	No	67% agreed to be unrelated
90	Yes	67% agreed to be related	No	67% agreed to be unrelated
91	No	100% agreed to be unrelated	No	67% agreed to be unrelated
92	Yes	67% agreed to be related	No	67% agreed to be unrelated
93	No	67% agreed to be unrelated	No	67% agreed to be unrelated

94	Yes	67% agreed to be related	Yes	100% agreed to be related
95	Yes	67% agreed to be related	No	67% agreed to be unrelated
96	Yes	67% agreed to be related	No	67% agreed to be unrelated
97	Yes	67% agreed to be related	No	100% agreed to be unrelated
98	No	100% agreed to be unrelated	No	67% agreed to be unrelated
99	No	67% agreed to be unrelated	No	67% agreed to be unrelated

Inter-rater reliability: Fleiss kappa tests were performed to assess the level of agreement between the experts. The results indicate slight agreement between them for both ATM (0.06) and CCTV (0.07) goals.

5.3.3 Distribution of steps within the groups

This section explains the analysis of the collected scripts' steps for each script group and compares them with each other.

Tables 5.12, 5.13, and 5.14 show the number of steps related to the different goals in the three groups of scripts, and Table 5.15 shows descriptive statistics about the relationship between the collected scripts and goals. As shown in these tables, although the number of steps related to each of the goal in different script groups are not very different, there are some differences:

Table 5.12: The proportion of information related to each goal mentioned by each scripter in $SG_{G_{atm}}$

number	number of steps related to G_{atm}	number of steps related to G_{atm} but not to G_{cctv}	number of steps related to G_{cctv}	number of steps related to G_{cctv} but not to G_{atm}	number of steps related to both G_{atm} and G_{cctv}	number of steps related to neither G_{atm} nor G_{cctv}
1	15	15	3	3	0	13
2	13	11	5	3	2	11
3	15	12	10	7	3	10
4	12	12	1	1	0	13
5	12	11	2	1	1	13
6	15	13	4	2	2	12
7	15	13	2	0	2	9
8	8	8	2	2	0	10
9	11	10	2	1	1	9
10	12	10	5	3	2	8
11	9	8	3	2	1	10
12	13	11	3	1	2	10
13	8	7	2	1	1	9
14	14	13	2	1	1	7
15	7	6	4	3	1	11
16	12	11	3	2	1	11
17	15	12	4	1	3	5
18	12	11	2	1	1	8
19	9	9	1	1	0	11
20	10	9	3	2	1	9
21	9	8	2	1	1	9
22	9	8	1	0	1	10
23	12	8	5	1	4	6
24	10	8	2	0	2	7
25	10	9	1	0	1	9
26	12	11	1	0	1	8
27	10	8	3	1	2	6
28	8	6	4	2	2	8
29	8	8	0	0	0	6
30	11	10	1	0	1	6
31	9	9	0	0	0	7
32	11	9	2	0	2	3
33	11	10	2	1	1	7
34	10	10	1	1	0	10
35	7	7	1	1	0	8
36	8	7	1	0	1	7
37	8	8	1	1	0	5
38	7	7	0	0	0	7
39	7	6	1	0	1	2
40	9	9	0	0	0	3
41	9	9	0	0	0	5
42	6	5	1	0	1	4
total	438	392	93	47	46	342
average	10.43	9.33	2.21	1.12	1.1	8.14

Table 5.13: The proportion of information related to each goal mentioned by each scripter in $SG_{G_{cctv}}$

number	number of steps related to G_{atm}	number of steps related to G_{atm} but not to G_{cctv}	number of steps related to G_{cctv}	number of steps related to G_{cctv} but not to G_{atm}	number of steps related to both G_{atm} and G_{cctv}	number of steps related to neither G_{atm} nor G_{cctv}
1	13	11	11	9	2	14
2	13	11	5	3	2	9
3	11	9	10	8	2	11
4	12	10	4	2	2	12
5	11	10	3	2	1	11
6	11	9	7	5	2	10
7	11	10	3	2	1	12
8	13	12	4	3	1	9
9	5	4	5	4	1	12
10	13	11	3	1	2	13
11	9	8	4	3	1	9
12	9	8	4	3	1	12
13	10	8	5	3	2	10
14	10	9	1	0	1	11
15	8	7	2	1	1	9
16	9	8	2	1	1	11
17	9	9	1	1	0	9
18	8	8	2	2	0	11
19	10	8	2	0	2	8
20	11	9	5	3	2	11
21	9	8	3	2	1	10
22	6	6	3	3	0	10
23	7	6	3	2	1	11
24	5	5	1	1	0	11
25	7	6	1	0	1	8
26	11	9	3	1	2	9
27	8	6	2	0	2	7
28	8	7	4	3	1	8
29	7	5	5	3	2	9
30	7	5	2	0	2	8
31	8	8	0	0	0	7
32	6	6	1	1	0	6
33	9	8	3	2	1	6
34	4	4	1	1	0	7
35	9	8	3	2	1	6
36	4	3	1	0	1	7
37	6	4	3	1	2	4
38	5	5	0	0	0	4
39	7	6	2	1	1	5
total	339	294	124	79	45	357
average	8.69	7.54	3.18	2.03	1.15	9.15

Table 5.14: The proportion of information related to each goal mentioned by each scripter in $SG_{G_{control-group}}$

number	number of steps related to G_{atm}	number of steps related to G_{atm} but not to G_{cctv}	number of steps related to G_{cctv}	number of steps related to G_{cctv} but not to G_{atm}	number of steps related to both G_{atm} and G_{cctv}	number of steps related to neither G_{atm} nor G_{cctv}
1	14	13	4	3	1	13
2	13	13	1	1	0	11
3	13	11	10	8	2	12
4	9	9	2	2	0	11
5	13	11	6	4	2	13
6	10	8	5	3	2	13
7	13	12	1	0	1	11
8	8	7	5	4	1	12
9	9	7	5	3	2	14
10	14	12	3	1	2	10
11	10	9	2	1	1	9
12	7	7	1	1	0	9
13	9	8	2	1	1	10
14	8	8	0	0	0	8
15	8	8	2	2	0	11
16	10	8	5	3	2	9
17	6	6	3	3	0	12
18	9	8	3	2	1	11
19	9	8	3	2	1	10
20	7	7	2	2	0	10
21	8	8	2	2	0	11
22	11	9	3	1	2	9
23	7	6	3	2	1	9
24	10	10	0	0	0	9
25	5	4	3	2	1	12
26	10	9	2	1	1	8
27	8	8	1	1	0	10
28	8	8	1	1	0	9
29	7	6	1	0	1	7
30	10	9	2	1	1	9
31	7	7	0	0	0	9
32	8	8	0	0	0	7
33	9	9	0	0	0	8
34	8	8	0	0	0	6
35	5	5	0	0	0	8
36	7	7	0	0	0	8
37	7	7	0	0	0	6
38	10	9	2	1	1	6
39	6	6	1	1	0	9
40	6	6	0	0	0	6
41	7	7	0	0	0	3
42	5	4	1	0	1	3
43	4	4	1	1	0	3
total	372	344	88	60	28	394
average	8.65	8	2.05	1.4	0.65	9.16

Table 5.15: Number of steps to different goals within the three script groups

	ATM group	CCTV group	Control Group	Total
Total number of steps	827	749	826	2402
Average number of steps in each script	19.69	19.21	19.21	19.37
Related to G_{atm}				
Total number of steps identified to be related to ATM goal	438	339	372	1149
Average number of steps identified to be related to ATM goal	10.43	8.69	8.65	9.26
Total number of steps related to the goal ATM in aggregated script	48	30	28	53
Highest number of steps related to the goal ATM in one script	15	13	14	
Lowest number of steps related to the goal ATM in one script	6	4	4	
Related to G_{cctv}				
Total number of steps identified to be related to CCTV goal	93	124	88	305
Average number of steps identified to be related to CCTV goal	2.21	3.18	2.05	2.46
Total number of steps related to the goal CCTV in aggregated script	22	24	16	34
Highest number of steps related to the goal CCTV in one script	10	11	10	
Lowest number of steps related to the goal CCTV in one script	0	0	0	
Related to $G_{atm}\overline{G_{cctv}}$				
Total number of steps identified to be related to ATM goal not related to CCTV	392	294	344	1030
Average number of steps identified to be related to ATM goal not related to CCTV	9.33	7.54	8	8.31
Total number of steps related to the goal ATM but not related to CCTV in aggregated script				40
Related to $\overline{G_{atm}}G_{cctv}$				
Total number of steps identified to be related to CCTV goal not related to ATM	47	79	60	186
Average number of steps identified to be related to CCTV goal not related to ATM	1.12	2.03	1.4	1.5
Total number of steps related to the goal CCTV but not related to ATM in aggregated script				21
Related to $G_{atm}G_{cctv}$				
Total number of steps identified to be related to both goals	46	45	28	119
Average number of steps identified to be related to both goals	1.1	1.15	0.65	0.96
Related to $\overline{G_{atm}G_{cctv}}$				
Total number of steps identified to be related to none of the goals	342	331	394	1067
Average number of steps identified to be related to none of the goals	8.14	8.49	9.16	8.6

In total, 1149 steps (9.27 per script) were identified to be related to the goal ATM (G_{atm}).

The average number of steps related to the goal ATM per script is higher for SG_{atm} (10.43) than for the other groups: SG_{cctv} (8.69) and $SG_{\emptyset}$ (8.65),

SG_{atm} has the highest total number of steps related to the goal ATM (48 steps), which is followed by SG_{cctv} (30), and $SG_{\emptyset}$ (28),

The script with the highest number of steps related to the goal ATM is in SG_{atm}, with 15 steps, and the lowest ones with 4 steps were in SG_{cctv} and $SG_{\emptyset}$,

In total, 305 steps (2.46 per script) were identified to be related to the goal CCTV (G_{cctv}).

The average number of steps related to the goal CCTV per script is higher for SG_{cctv} (3.18) than for the other groups: SG_{atm} (2.21) and $SG_{\emptyset}$ (2.05),

SG_{cctv} has the highest total number of steps related to the goal CCTV (24 steps), which is followed by SG_{atm} (22), and $SG_{\emptyset}$ (16),

The script with the highest number of steps related to the goal CCTV is in SG_{cctv}, with 11 steps. All the 3 groups have some scripts with no step related to SG_{cctv}, however, SG_{cctv} has the lowest number of scripts with no steps related to CCTV goal (2) compared to the other two groups, SG_{atm} (5) and $SG_{\emptyset}$ (11).

In total, 1030 steps (8.31 per script) were identified to be related to the goal ATM

but not related to CCTV ($G_{atm}\overline{G_{cctv}}$).

The average number of steps related to the goal ATM but not to CCTV per script is higher for SG_{atm} (9.33) than the other two groups: SG_{cctv} (7.54) and $SG_{\emptyset}$ (8),

In total, 186 steps (1.5 per script) were identified to be related to the goal CCTV but not related to ATM ($\overline{G_{atm}}G_{cctv}$).

The average number of steps related to the goal CCTV but not to ATM per script is higher for SG_{cctv} (2.03) than the other two groups: SG_{atm} (1.12) and $SG_{\emptyset}$ (1.4),

In total, 119 steps (0.96 per script) were identified to be related to both the goals ($G_{atm}G_{cctv}$).

The average number of steps related to both the goals is 1.15 in SG_{cctv} that is followed by 1.1 in SG_{atm}, and 0.65 in $SG_{\emptyset}$.

In total, 1067 steps (8.6 per script) were identified to be related to neither of the goals ($\overline{G_{atm}G_{cctv}}$).

The average number of steps related to none of the goals is 9.16 in $SG_{\emptyset}$ that is followed by 9.15 in SG_{cctv}, and 8.14 in SG_{atm}.

From the total 99 steps in the aggregated script, 53 were recognised to be related to the goal ATM (G_{atm}), 40 to be related to the goal ATM but not to CCTV ($G_{atm}\overline{G_{cctv}}$), 34 to be related to the goal CCTV (G_{cctv}).

The number of steps related to ATM goal were significantly higher in all groups than the number of steps related to CCTV goal, which is 4.71 times higher in ATM group, 2.73 time in CCTV group, 4.22 times in control group, and 3.76 times in all the scripts.

The highest number of steps related to ATM goal in a single script (15) is slightly higher the same as the highest number of steps related to the goal CCTV in a single script (11).

5.3.4 Analysing normality

More descriptive analyses of the data are presented in Tables 5.12, 5.13, and 5.14 and are shown in Figure 5.5. As it can be seen in Figure 5.5.a:

- For the number of steps related to G_{atm} in $SG_{G_{atm}}$, the z-value for skewness (1.08) is in the range of -1.96 to 196 but the kourtosis z-value (-2) is out of the range; so they do not have normal distribution.

- For the number of steps related to G_{atm} in $SG_{G_{cctv}}$, the z-value for skewness (1.74) is in the range of -1.96 to 196 but the kourtosis z-value (3.94) is out of the range; so they do not have normal distribution.

- For the number of steps related to G_{atm} in $SG_{G_{\emptyset}}$, both the z-values for skewness (1.21) and kourtosis (-0.74) are in the range of -1.96 to 196; so they have normal distribution.

And as shown in Figure 5.5.b:

- For the number of steps related to G_{cctv} in $SG_{G_{cctv}}$, both the z-values for skewness (4.23) and kourtosis (9.43) are out of the range of -1.96 to 196; so they do not have normal distribution.

- For the number of steps related to G_{cctv} in $SG_{G_{atm}}$, both the z-values for skewness (6.66) and kourtosis (20.9) are out of the range of -1.96 to 196; so they do not have normal distribution.

- For the number of steps related to G_{cctv} in $SG_{G_{\emptyset}}$, both the z-values for skewness (4.97) and kourtosis (11.19) are out of the range of -1.96 to 196; so they do not have normal distribution.

related to the goal ATM in ATM group		*/standard error*	*related to the goal ATM in CCTV group*		*/standard error*	*related to the goal ATM in control group*		*/standard error*
Mean	10.32		Mean	8.95		Mean	8.73	
Standard Error	0.38		Standard Error	0.47		Standard Error	0.38	
Median	10		Median	9		Median	8	
Mode	9		Mode	9		Mode	8	
Standard Deviation	2.5		Standard Deviation	3		Standard Deviation	2.5	
Sample Variance	6.5		Sample Variance	8.98		Sample Variance	6.3	
Kurtosis	-0.76	-2	Kurtosis	1.85	3.94	Kurtosis	-0.28	-0.74
Skewness	0.41	1.08	Skewness	0.82	1.74	Skewness	0.46	1.21
Range	9		Range	15		Range	10	
Minimum	6		Minimum	4		Minimum	4	
Maximum	15		Maximum	19		Maximum	14	
Sum	454		Sum	358		Sum	384	
Count	44		Count	40		Count	44	

(a) Number of steps related to the goal ”To improve ATM design”

related to the goal CCTV in CCTV group		*/standard error*	*related to the goal CCTV in ATM group*		*/standard error*	*related to the goal CCTV in control group*		*/standard error*
Mean	3.1		Mean	2.07		Mean	2.02	
Standard Error	0.371		Standard Error	0.29		Standard Error	0.32	
Median	3		Median	2		Median	2	
Mode	3		Mode	1		Mode	0	
Standard Deviation	2.35		Standard Deviation	1.89		Standard Deviation	2.1	
Sample Variance	5.53		Sample Variance	3.55		Sample Variance	4.4	
Kurtosis	3.5	9.43	Kurtosis	6.06	20.9	Kurtosis	3.58	11.19
Skewness	1.57	4.23	Skewness	1.93	6.66	Skewness	1.59	4.97
Range	11		Range	10		Range	10	
Minimum	0		Minimum	0		Minimum	0	
Maximum	11		Maximum	10		Maximum	10	
Sum	124		Sum	91		Sum	89	
Count	40		Count	44		Count	44	

(b) Number of steps related to the goal ”To improve CCTV/Surveillance design”

Figure 5.5: Distribution of number of steps related to the goals within the three script groups

5.3.5 Testing hypothesis

The (null) hypothesis to be tested here is:

> H0: Scripters who are aware of the crime scripting goal do not include more information related to the given goal than scripters who are not aware of that goal.

And the alternative hypothesis is:

> H1: Scripters who are aware of the crime scripting goal include more information related to the given goal compare to the scripters who are not aware of that goal.

This hypothesis has been tested for both interventions, and for six goal combinations in each of them. The results of the conducted tests are shown in Table 5.16 and described below:

Comparing the steps related to G_{atm}

A Kruskal-Wallis H test showed that there is a statistically significant difference in the number of steps related to ATM in the crime scripts generated by the three scripter groups (H = 11.09, $p < 0.01$), with a mean rank number of steps of 10.43 for the scripts in the ATM group, and 8.69 for those in the CCTV group, and 8.65 in the control group .

Pairwise comparison using Mann-Whitney U test showed there are significant dif-

ferences between the number of steps related to G_{atm} in $SG_{G_{atm}}$ vs $SG_{G_{cctv}}$ ($p < 0.05$) and also $SG_{G_{atm}}$ vs $SG_{G_{\emptyset}}$ ($p < 0.01$), but that is no significant difference between the number of steps related to G_{atm} in $SG_{G_{cctv}}$ vs $SG_{G_{\emptyset}}$ ($p > 0.05$). More specifically, $SG_{G_{atm}}$ had significantly more steps related to G_{atm} than $SG_{G_{cctv}}$ and $SG_{G_{atm}}$ had significantly more steps related to G_{atm} than $SG_{G_{\emptyset}}$.

Comparing the steps related to $G_{atm}\overline{G_{cctv}}$

A Kruskal-Wallis H test showed that there is a statistically significant difference in the number of steps related to ATM but not related to CCTV in the crime scripts generated by the three scripter groups ($H = 11.9$, $p < 0.01$), with a mean rank number of steps of 9.33 for the scripts in the ATM group, and 7.54 for those in the CCTV group, and 8 in the control group .

Pairwise comparison using Mann-Whitney U test showed there are significant differences between the number of steps related to ATM but not related to CCTV in $SG_{G_{atm}}$ vs $SG_{G_{cctv}}$ ($p < 0.05$) and also $SG_{G_{atm}}$ vs $SG_{G_{\emptyset}}$ ($p < 0.01$), but that is no significant difference between the number of steps related to $G_{atm}\overline{G_{cctv}}$ in $SG_{G_{cctv}}$ vs $SG_{G_{\emptyset}}$ ($p > 0.05$). More specifically, $SG_{G_{atm}}$ had significantly more steps related to $G_{atm}\overline{G_{cctv}}$ than $SG_{G_{cctv}}$ and $SG_{G_{atm}}$ had significantly more steps related to $G_{atm}\overline{G_{cctv}}$ than $SG_{G_{\emptyset}}$.

Comparing the steps related to G_{cctv}

A Kruskal-Wallis H test showed that there is a statistically significant difference in

the number of steps related to CCTV in the crime scripts generated by the three scripter groups (H = 8.36, $p < 0.05$), with a mean rank number of steps of 3.18 for the scripts in the CCTV group, and 2.21 for those in the ATM group, and 2.05 in the control group.

Pairwise comparison using Mann-Whitney U test showed that there is significant difference between the number of steps related to CCTV in $SG_{G_{cctv}}$ vs $SG_{G_\emptyset}$ ($p < 0.05$), but there are no significant differences between the number of steps related to G_{cctv} in $SG_{G_{cctv}}$ vs $SG_{G_{atm}}$ ($p > 0.05$) or $SG_{G_{atm}}$ vs $SG_{G_\emptyset}$ ($p > 0.05$). More specifically, $SG_{G_{cctv}}$ had significantly more steps related to G_{cctv} than $SG_{G_\emptyset}$.

Comparing the steps related to $\overline{G_{atm}}G_{cctv}$

A Kruskal-Wallis H test showed that there is a statistically significant difference in the number of steps related to CCTV but not related to ATM in the crime scripts generated by the three scripter groups (H = 6.64, $p < 0.05$), with a mean rank number of steps of 2.03 for the scripts in the CCTV group, and 1.12 for those in the ATM group, and 1.4 in the control group.

Pairwise comparison using Mann-Whitney U test showed that is significant difference between the number of steps related to CCTV but not related to ATM in $SG_{G_{cctv}}$ vs $SG_{G_{atm}}$ ($p < 0.05$), but there are no significant differences between the number of steps related to $\overline{G_{atm}}G_{cctv}$ in $SG_{G_{cctv}}$ vs $SG_{G_\emptyset}$ ($p > 0.05$) or $SG_{G_{atm}}$ vs $SG_{G_\emptyset}$ ($p > 0.05$). More specifically, $SG_{G_{cctv}}$ had significantly more steps related to $\overline{G_{atm}}G_{cctv}$ than $SG_{G_{atm}}$.

Comparing the steps related to $G_{atm}G_{cctv}$

A Kruskal-Wallis H test showed that there is a statistically significant difference in the number of steps related to both the goals in the crime scripts generated by the three scripter groups (H = 6.64, $p < 0.05$), with a mean rank number of steps of 1.15 for the scripts in the CCTV group, and 1.1 for those in the ATM group, and 0.65 in the control group.

Pairwise comparison using Mann-Whitney U test showed a significant difference between the number of steps related to both the goals in $SG_{G_{cctv}}$ vs $SG_{G_{\emptyset}}$ ($p < 0.01$), but there are no significant differences between the number of steps related to $G_{atm}G_{cctv}$ in $SG_{G_{cctv}}$ vs $SG_{G_{atm}}$ ($p > 0.05$) or $SG_{G_{atm}}$ vs $SG_{G_{\emptyset}}$ ($p > 0.05$). More specifically, $SG_{G_{cctv}}$ had significantly more steps related to $G_{atm}G_{cctv}$ than $SG_{G_{\emptyset}}$.

Comparing the steps related to $\overline{G_{atm}G_{cctv}}$

A Kruskal-Wallis H test showed that there is no significant difference in the number of steps related to neither of the goals ATM and CCTV in the crime scripts generated by the three scripter groups (H = 3.57, $p > 0.05$)

Table 5.16 summarises the results of the performed statistical tests.

Table 5.16: Results of the executed statistical tests

KW all three	alpha = 0.05			
	H		p	significance
related to ATM	11.088	(2, N=124)	0.004	significant
related to ATM not CCTV	11.897	(2, N=124)	0.003	significant
related to CCTV	8.36	(2, N=124)	0.015	significant
related to CCTV not ATM	6.635	(2, N=124)	0.036	significant
related to both	9.29	(2, N=124)	0.01	significant
related to none	3.567	(2, N=124)	0.168	not significant

MW SG_{atm} vs SG_{cctv}	alpha = 0.05	Bonfferoni = 3		
	z-score	u	p	significance—after correction
related to ATM	-2.655	540	0.008	significant
related to ATM not CCTV	-3.153	489	0.002	significant
related to CCTV	-2.236	586.5	0.025	not significant
related to CCTV not ATM	-2.542	559	0.011	significant
related to both	-0.695	750	0.487	not significant
related to none	-0.629	753	0.529	not significant

MW SG_{atm} vs $SG_{\emptyset}$	alpha = 0.05	Bonfferoni = 3		
	z-score	u	p	significance—after correction
related to ATM	-3.056	558	0.002	significant
related to ATM not CCTV	-2.724	597	0.006	significant
related to CCTV	-0.722	822.5	0.47	not significant
related to CCTV not ATM	-0.845	811	0.398	not significant
related to both	-2.212	667.5	0.027	not significant
related to none	-1.797	700	0.072	not significant

MW SG_{cctv} vs $SG\emptyset$	alpha = 0.05	Bonfferoni = 3		
	z-score	u	p	significance—after correction
related to ATM	-0.262	810.5	0.793	not significant
related to ATM not CCTV	-0.626	772	0.531	not significant
related to CCTV	-2.662	556	0.008	significant
related to CCTV not ATM	-1.685	662	0.092	not significant
related to both	-2.924	543	0.003	significant
related to none	-1.281	702	0.2	not significant

5.4 Discussion

The experiment presented in this chapter aimed to investigate one important but overlooked area in crime scripting: information selection. Although information selection has been studied in various other fields, it has been overlooked in the crime scripting field. Still, very little is known about *what type of information should be sought in constructing scripts?*, *what information is relevant to a crime script?*, or *what methods should be used for identifying relevant information to crime script?* The crime scripting literature currently has no answers to these questions.

Contributing to solving this problem, this study aimed to investigate one ignored factor in crime scripting process: goals. More specifically, to investigate *the effects of scripters' knowledge about the purposes or goals of crime scripting in scripters' information selection practices*. That is, to test its impact on the final scripts' content. This was accomplished by conducting an experiment. Three groups of participants generated scripts for the same crime event but with different treatments (application goals)— ATM goal (G_{atm}), CCTV goal (G_{cctv}), and no goal ($G_{\emptyset}$) (the control group). In total, 124 valid scripts were collected, coded, and integrated to an aggregated script. The relation between the aggregated script's step and goals were determined by a panel of experts, and the resulting relationship table was used to classify, analyse, and compare the scripts from each group of participants.

Scripters are more likely to include and write about objects or actions that they can observe, as the analyses found. To explain, two goals were given to the scripters groups:

ATM and CCTV. There was a greater number of steps related to the goal ATM in all three scripter groups than the number of steps related to CCTV goal— nearly four times more. In addition, all the collected scripts had some (four or more) steps related to ATM but 18 scripts had no steps related to CCTV.

Although these results may arise for various reasons, because the scripters could observe the ATM machine and the way the offenders and the victim were often interacting with the ATM could be a reason for this. That is, in the video, the actors had no interaction with CCTV. However, this needs a deeper investigation that can be investigated in a new research.

The proportion of irrelevant steps are fixes. Six goal combinations were used for testing the hypothesis and significant differences were observed in five of them. The only goal combination that observed no significant difference between the script's steps related to neither of the goals. Although different interpretations can be made for this result, one possible explanation is that the proportion of the number of unrelated steps (to the goals) are the same in all scripts regardless if they are goal-driven or not. However, again a more comprehensive study should be conducted to provide a more robust answer for this.

Goals should not affect scripts' length: The average number of steps in the scripts of the all three script groups were relatively similar ($\sim$19.5). The longest and shortest scripts in the three different groups were also relatively similar. This implies scripters (in average) write the same number of steps in their scripts regardless of

their given goal. That said, the steps in script groups ATM had a higher diversity, compared to the other groups. These could be a result from various factors e.g., the time spent writing the scripts or the scripters' understanding of the goal, but, again, having more accurate answers, requires a dedicated study.

Goals affect scripts' content: The results of the conducted statistical tests support the stated hypothesis which expected *scripters who are aware of the crime scripting goal would include more information related to the given goal compared to the scripters who are not aware of that goal*. Informing scripters about crime scripting goals would result in having scripts that contain more steps related to the informed goals. Considering the need for a more systematic, structured crime scripting approach, to improve the shortcoming of the existing crime scripting approaches, this motivates to involve goals in the development of such a new structured crime scripting method.

There were some limitations in conducting this experiment. One of the main limitations was access to participants. An ideal participant for this study would be someone with considerable education or experience in a security or crime related field with a comprehensive understanding of SCP and crime scripting. The potential population for such a study is very limited and consequently accessing them is very challenging. Consequently, this study utilised students who would be expected to have similar (but obviously less) knowledge. Furthermore, and even with this population to draw a sample from, the number of participants of the study in this experiment was 139 people (< 50 in each group) which is relatively small. Having

such a small sample and groups means there is a smaller chance of having identical groups which could affect the results. To minimise this risk this study used a random assignment for constructing the groups. A randomisation check was also run that suggests the groups were not significantly different in term of the factors that may affect the final results, e.g., age and crime prevention or scripting experience of participants between the groups. Moreover, two treatment's values were given to the groups and their effects were measured independently that should also reduce the chance of having random results. In other words, the hypothesis was tested with multiple sets of data to gain more robust results. A future study may however want to revisit these analyses using a larger and more knowledgeable (about SCP and crime scripting) sample.

The other main limitation of the study was the maximum length of the experiment. If more time was available, the scripters training process could be more comprehensive, e.g., by providing participants with longer training about goal-driven information selection in crime scripting or the value of information within crime scripts in identifying SCP measures.

In addition, this study used experts' opinion to make judgement about the relationship between individual steps and the given goals. There is however a possible serious limitation regarding this about if their judgement is correct. Fixing for this is however not simple as there is a limited number of experts in crime scripting. As such, and although this study attempted to mitigate possible effects from this by using inter-rater and intra-rater tests, the results may still have been affected by this

and this may warrant further investigation in future studies.

Finally, the validity of the results is limited by the fact that experts were only in 'slight agreement' when deciding which goals were related to the different steps. With only three experts, the majority rule of two out of three experts (67%) was used to classify all the steps for which there was no consensus, i.e. 75% of the script. A greater number of experts would allowed me to increase the acceptance level and the reliability of the results (Noda, Kraemer, Yesavage & Periyakoil 2001). With 5 experts, for instance, an 80% acceptance level, which corresponds to four out of five experts, could have been selected. Unfortunately, having more than three experts in this study was not possible at the time. Another limitation concerns the background knowledge of the experts. With some training sessions, it would have been possible to ensure that classification decisions were based on an agreed set of rules, which could have improved the agreement score (Landis & Koch 1977). Replicating this study with the proposed changes would help draw stronger conclusions about the existence of a relationship between scripters awareness of the crime scripting goal and the likelihood that they include a piece of information related to that goal.

Chapter 6

Goal-driven crime scripting framework

The systematic review presented in Chapter 3 supported Ekblom & Gill (2016), Leclerc (2017) and suggested a growing interest in crime scripting. Despite this, existing crime scripting practice has many critical limitations that might impact the quality of the scripts. In turn, it can also, for example, impact their ability to identify suitable interventions and reduce crime. As such, Chapter 5 suggested one possible improvement of the scripting process: informing scripters about the script applications goals. Goals would provide a direction for scripters in their scripting tasks. However, this modification on its own does not completely address the issue. A number of questions remain such as how to identify the goals for a specific application, how to develop a completely new crime script, and what activities need to be followed and completed in the script development process. All

those are the focus of this chapter and are addressed through the creation of a goal-driven crime scripting framework.

To this end, this chapter begins by presenting a crime scripting process model that serves as the conceptual basis for the proposed crime scripting framework. This model was developed based on the data collected in the systematic review reported in chapter 3. The chapter continues with a background about goal-based methods and business process models followed by a description of the crime scripting framework. The validation of the proposed method is then presented, which includes an example illustrating the development of a crime script using the proposed framework. Finally, the chapter discusses how this framework can address some of the shortcomings of existing scripting practice.

6.1 Crime scripting process model

6.1.1 Introduction

The systematic review, presented in chapter 3, found no study with a comprehensive or clear list of the activities involved in crime scripting process. However, there were some details about those activities including:

- Data requirements: Willison (2006*a*) and Brayley et al. (2011) provided details about the data needed to generate scripts, where they listed typical data sources used in police investigations, and argued the need for gathering com-

plementary data,

- Script's components: Cornish (1994) and Ekblom & Tilley (2000) included some details about the components of a crime script and listed their identified components.

- Organising and visualising information: Beauregard et al. (2007) and Cornish & Clarke (2008) illustrated scripts using different visualisation models.

- Assessment: Borrion (2013), Hutchings & Holt (2015), and Dehghanniri et al. (2015) stressed the need for assessing crime scripts.

Despite the potential value of these, they have not yet been synthesised, integrated, or organised as a whole into a coherent process model.

6.1.2 The method

The activities required to generate a crime script were identified in the systematic review. The collected information was then compiled and reviewed to determine whether certain activities should be clustered together (when they were considered semantically similar) or alternatively split into multiple activities (when one activity referred to more than one sub-activity). An initial process model was then created, taking into account the presence of order dependencies between all pairs of activities. The resulted process model is described next.

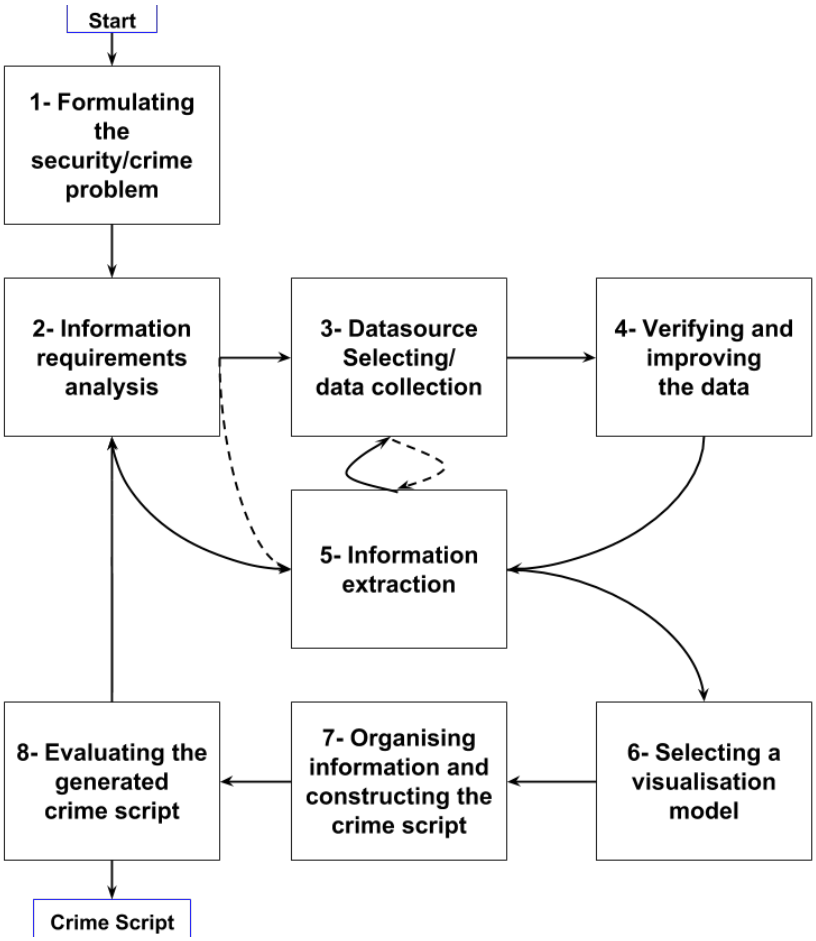

Figure 6.1: Crime scripting process model

6.1.3 Crime scripting process model

Figure 6.1 represents the crime scripting model generated using the aforementioned method. As shown in this figure, the model comprises of eight (not necessarily linear) stages. Note that not all stages are necessarily required or used in generating a crime script nor do they only need to be completed once and so they can be omitted or repeated as needed.

1. Formulating the problem: In the first instance, the crime phenomenon to be modelled is identified— e.g. burglary. In this stage, analysts should also spec-

ify how and where the resulting model will be used. This is because what is expected from a crime script will largely depend on its intended application. For example, a crime script created to support the design of a burglary prevention measure may need to be more detailed than one used to assess the risk of a burglary.

2. Information requirements: The purpose of this stage is to derive the requirements concerning the information to include in the crime script. That is, preferably based on the goal of the application. The output of this phase is critical to the quality of the future script as it informs the data collection stage. The information requirements can be divided into two categories: i) those specifying what types of states, events, or activities should be modelled and ii) those specifying what aspects of those states, events, or activities should be detailed.

   As an example, consider a study previously published by Dehghanniri et al. (2015). First, after identifying the application of the crime scripts (i.e. assessing the potential effects of different interventions on a particular type of identity theft), they considered the purpose of the script and concluded that it should represent successful attacks (i.e. sequences of actions that would result in identify theft despite the presence of the authentication system) as well as attacks that are unsuccessful as a direct or indirect effect of the measure. Second, they decided that the elements to model should be the actions contributing to the attack, those conducting them, the resources involved, and

how the latter were used during the attack.

The two types of requirements that could be sought here are, therefore:

- *Requirements concerning states, events and activities*: Cornish (1994) made suggestions about the events that should appear in crime scripts. He pointed to 'knowledge about procedural aspects of and procedural requirements of crime commission' and information about offenders' subjective accounts of the crime commission process as the required information for crime scripting.

  In many studies, the events to include in the crime script were often defined through two questions: what happened that is relevant to the crime and how it happened? (De Bie et al. 2015, Jacques & Bernasco 2013).

- *Requirements concerning components*: drawing on Schank & Abelson (1977), Cornish (1994) introduced a list of crime script components: 'scenes, paths, actions, roles, props, and locations'. Scenes are high-level components of scripts that can be used for organising the structure of the scripts Tompson & Chainey (2011); they were used in several studies to model the stages of the crime commission process. Studies also identified components such as *actors* and *locations* (Chiu et al. 2011, Hiropoulos et al. 2013). In addition, Tompson & Chainey (2011) pointed to the description of the required skills, resources, and effort

involved in carrying out the crime.

3. Data source selection: once the information requirements are specified, analysts should identify the source of the data from which this information will be extracted. As discussed in Chapter 3, most of the reviewed studies rely on secondary data sources, including court data (Chiu et al. 2011) and offender testimonies in police reports (De Vries 2012, Khey & Sainato 2013). Others, such as Brayley et al. (2011), however also gathered primary data as a complementary source.

4. Verifying and improving the data: In this step, the quality of the available data is assessed and improved where appropriate. Crime scripts are often built using secondary data sources that do not necessarily encompass all the relevant aspects of the crime script. As such, their reliability may be limited. In this case, better information can be obtained using more data. For example, if the initially selected data source is not complete enough, the use of multiple secondary data sources or collection of complementary data can be used to improve completeness (Brayley et al. 2011). As an example, Basamanowicz & Bouchard (2011) used court proceedings as their main source of data but also employed 'secondary data sources to verify and supplement the court case documents'.

5. Information extraction: this step aims to identify and extract information from the available data. For this, a targeted search can be performed based on

the specified information requirements. Among the previous studies some authors used a structured method to achieve this. For example, Cornish & Clarke (2008) and Tompson & Chainey (2011) used a template for identifying the information to be in the final script. They first determined the main scenes of the crime events, before searching for detailed information related to the each of them.

6. Selecting a visualisation model: considering the application and users of the crime script, and the available information, a visualisation model is selected to represent the final script. Three visualisation models feature in the reviewed literature: tables, flowcharts, and narratives. Most of the reviewed studies relied on a single visualisation model although some of them used a mixture (e.g., Leclerc et al. 2011, Osborne & Capellan 2015).

7. Organising information: after identifying the source of information and selecting the visualisation model, the extracted information must be organised to construct the final crime script. In this step, the information is also reviewed and revised to improve the script's readability and consistency.

8. Evaluating the generated crime script: This is the last step of the crime scripting process. The generated script should be assessed based on a selected list of criteria (e.g., accuracy or traceability) (Borrion 2013). Although the need for assessing crime scripts was mentioned in several studies (Borrion 2013, Dehghanniri et al. 2015, Hutchings & Holt 2015), none of the reviewed stud-

ies explicitly addressed this.

6.1.4 Model validation

The validation of the model was conducted by assessing whether i) any important activity had been omitted, comparing the listed activities and the information extracted from the reviewed publications and ii) checking if there was any logical flaw. That is, by considering whether the different steps could be carried out using the information provided by the previous steps. To give an example, *extracting information* should be done after *identifying the data source*, so it came after *identifying data* stage whereas *assessment of crime script* has to be performed after a first version of the crime script is produced.

The model was then reviewed and discussed with a second reviewer. Some modifications were then applied to the model at this stage. Then, a third researcher has experience working with crime script development reviewed the model. Finally, in a group discussion it was argued whether i) the model was an accurate representation of the process they followed to construct crime scripts, ii) no important activity appears to be missing, iii) no unnecessary activity seems to have been included, and iv) the organisation of the activities is reasonable.

6.1.5 Discussion

This model is the first attempt to provide an overall description of the process used to generate high-quality crime scripts; including a description of the different stages

and their logical dependencies. This crime scripting process model was created to support researchers and practitioners in generating crime scripts and reporting the results. It should also support reviewers in evaluating the methods described in future articles, for example, by contributing to identifying missing or poorly documented stages. In this thesis, the model is used as the basis for development of the proposed goal-driven crime scripting framework.

The model was inspired by publications in the fields of business process modelling and software engineering life-cycle. For example, the first step of the proposed model, i.e. formulating the problem, was not explicitly considered in any of the existing crime scripting studies. However, it was included in our model, which was inspired from similar models, e.g., from software engineering or risk analysis where this activity aims to define the problem and applications' objectives. Without this step, it is not clear *why we should generate the crime script?* Or *what are the objectives of the application?*

6.2 Goal-driven crime scripting framework

This section describes the proposed goal-driven crime scripting method. This is developed based on the crime scripting process model that was described in section 6.1.3 plus the goal-based methods and business process model analysis and design that are explained next.

6.2.1 Goal-based approaches

A goal-driven approach refers to the use of goals in a process or activity. This technique has been deployed in various disciplines, for example, requirements engineering (RE). This study therefore relies on RE literature in designing its proposed goal-driven crime scripting framework.

Goal-driven technique has received a lot of attention among scholars in the last few decades, though it also appears in various older studies under different names. As explained by Van Lamsweerde (2001), many informal system development methodologies had some form of goal-based analysis, albeit known as context analysis (Ross & Schoman Jr 1977), definition study (Hice 1978), participative analysis (Mumford 1981), and other names. In those studies the system under consideration is typically analysed in its organisational, operational, and technical settings. Problems are then highlighted and opportunities are identified. High-level goals are then determined and refined to address the highlighted problems and meet the opportunities. Such practice has led requirements documentation standards to require a specific document section devoted to the objectives that the system should meet. Van Lamsweerde (2001) pointed out that reviewing the current state of the art in goal-oriented RE would not make much sense without first addressing the what, why, where, and when questions about this area of research.

What are goals? 'A goal is an objective the system under consideration should achieve'. Goals can be formulated at different levels of abstraction from very gen-

eral and high-level to very detailed and low-level. They can also cover different types of concerns including functional concerns such as the way in which the systems' functions should be implemented and developed (Van Lamsweerde 2001). In this research, goals refer to the objectives of the stakeholders of the crime-script-to-be and can be any person or party that can be affected by the script.

Why are goals needed? Considering goals in the crime script generation process can help in drawing the basic criteria for the way that a system is made or assessed. For example:

- Completeness is an important concern for developing different systems as 'goals provide a precise criterion for sufficient completeness' of a system or process (Yue 1987).

- Traceability and providing a rationale for the information appearing in a specification and a system's objective can be done using goals (Yu 1993). That is, by assessing whether there is a link/relation between a piece of information and one of the identified goals.

- Parsimony and avoiding irrelevant information in a specification is another important criterion. A goal or goals can provide a precise criterion for the pertinence of the specification in that a piece of information in a specification is pertinent with respect to a set of goals if there is a link between that information and one of the goals (Yue 1987).

- Conflicts among multiple viewpoints or goals is another concern in developing systems/products that can be managed (recognised and resolved) using goals (Nuseibeh, Kramer & Finkelstein 1994, Robinson 1989, Van Lamsweerde, Darimont & Letier 1998).

Who owns the goals? Various studies define different kind of goals. However, in general, a goal can belong to an individual user, a system in general, or an organisation as a whole (Cooper 1996, Dardenne, Van Lamsweerde & Fickas 1993).

What are the types of goals? Different types of goals may be concerned in an application, e.g., achieve, satisfy, maintain, avoid, or optimise (Dardenne et al. 1993).

What is goal refinement and abstraction? Goal refinement is the process through which goals are broken down into sub-goals. Goal abstraction proceeds in the opposite direction where sub-goals are merged should they relate to the same general goal. Goals can also be refined into super-goals by asking how these goals should be achieved while super-goals are found by asking why a certain goal is sought (Van Lamsweerde 2000).

Where are goals coming from? Goals can be explicitly stated by the stakeholders or in any preliminary material. However, 'most often they are implicit so that goal elicitation has to be undertaken'. Preliminary analysis is an important source for identifying goals e.g., by searching the keywords in the provided documents or interview transcript (Van Lamsweerde 2000). 'Once a preliminary set of goals and requirements is obtained and validated with stakeholders, [other] goals can

be identified by refinement and by abstraction; just by asking HOW and WHY questions about the goals/requirements already available, respectively' (Van Lamsweerde 2000, Van Lamsweerde, Darimont & Massonet 1995).

When should goals be made explicit? In a goal-driven requirements elicitation, goals must be identified and validated in the early phases of requirements engineering. They must be specified precisely to support the next steps of development including requirements elaboration, verification/validation, or conflict management.

6.2.2 Business process models

What is a Business Process Model (BPM)? A BPM illustrates how something is done and encompasses the activities that should take place for this to occur. This is a flow-oriented representation of a set of work that aims to achieve a goal or goals, e.g., building a product, serving a customer, etc. The essence of BPM is to understand how to do the right things in the right ways. This is originally focused on describing organisational processes, however, as it is a description of a given process, the same techniques can be used to explain similar processes.

There are different types of BPM. First, physical, for example, to describe the transformation of raw material to a product. Second, locational, for example, to explain transportation services. Third, transactional, for example, transformation of money. Lastly, informational, for example, to transform raw data to meaningful statements (Laguna & Marklund 2018, Ouyang, Dumas, Van Der Aalst, Ter Hofst-

ede & Mendling 2009). The latter is the one that matches most closely the current work.

What are the components of a BPM? The process architecture in a BPM can be characterised in terms of the following components:

- Inputs and outputs: inputs refer to what is provided from the environment and outputs refer to what the process would produce. These should be identified at the first step of developing a BPM as they help in understanding the boundaries of the process.

- Flow units: these are to define how the inputs proceed through various activities to produce the output.

- Network of activities: these define the required activities in the process, the relationship between them, and the order in which they are executed. Usually, having more simple individual activities results in a more complex network and vice versa.

- Resources: these are tangible and necessary assets of a process. While inputs are usually consumed in a process, resources are used.

- Information structure: this specifies the required and available information for making decisions and completing activities.

Considering the above components, a business process can be defined as 'a net-

work of connected activities [...] with well-defined boundaries and precedence relationships, which use resources to transform inputs into outputs for the purpose of satisfying [...] requirements' (Laguna & Marklund 2018).

How to make a good BPM? A good BPM application architecture should be conceptually comprehensible and meet real-world requirements. A good architecture uses the technique of divide-and-conquer to reduce a big or difficult problem to smaller more manageable parts. Also, and where possible, it solves each part by reusing an existing approach rather than inventing a new technology or method. To apply this technique some questions need to be answered such as:

- What is the problem to be solved?
- What are its parts? and
- How are they solved? (Havey 2005)

6.2.3 Goal-driven crime scripting framework

Figure 6.2 shows the proposed goal-driven crime scripting framework and the activities involved in this proposed method. It has six stages:

1. Problem definition: this is the first stage of the proposed framework that aims to clarify the security problem or crime type to be modelled. This includes:
    - Defining the security/crime issue to be scripted,

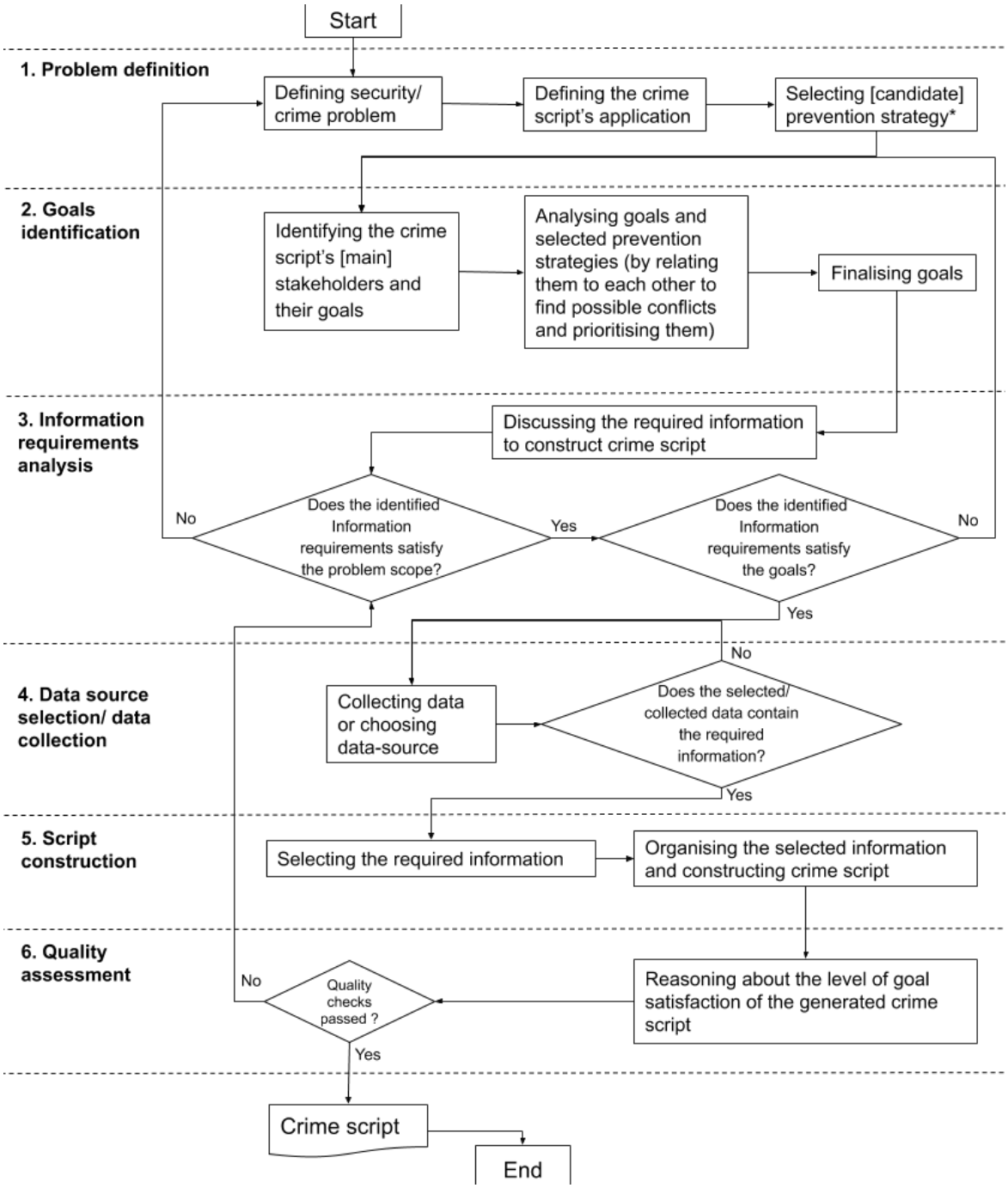

Figure 6.2: Goal-driven crime scripting framework

- Describing why the crime-script-to-be is being developed and where it will be used,

- Selecting the [candidate] prevention strategies for tackling the defined

problem. This can be from suggestions on how to mitigate the identified problem e.g., nominating some SCP techniques. In other cases, this can also be skipped if there is no preference.

2. Goal identification: this step is about identifying and analysing stakeholders (those who are affected by/can affect the crime process), and their goals and requirements, and will likely include:

   - Identifying the crime scripts [main] stakeholders (e.g. the offender, the victim, or security measure designer), and their goals and requirements (in the scope of the crime process).

   - Analysing goals by relating them to each other and also by relating them to the candidate prevention techniques Here, there is a possibility that the goals can conflict with each other, which can mean satisfying one goal would result in not satisfying another. These kinds of issues should be identified in this step.

   - Selecting and finalising the goals: when there are too many goals or requirements or there are some conflicting goals or requirements, goals should be prioritised and filtered. This will result in a final list of (selected) goals or requirements for the rest of the process.

3. Information requirements analysis: here, the information that should be included in the crime-script-to-be, considering the selected goals/requirements,

is discussed. The output from this stage would inform the level of detail required for the final script and the specific components that should be included in the final script (e.g., different actors, their actions, locations, etc.), and the scope of the model (e.g., focusing only on the crime scene, or considering a wider scope for example preparation, motivation, after crime points).

4. Data source selection/ data collection: in this stage, any existing relevant data sources are reviewed and it is determined whether further data collection is needed to complement the existing data. This consists of two steps:

    - Choosing data sources or collecting data; and

    - Reasoning whether the available data contains the required information.

5. Script construction: this is where the actual script is modelled following two steps:

    - Selecting the required information: this selection process is done based on the shortlisted goals and information requirements from steps 2 and 3,

    - Organising the elicited information and constructing crime script: finally, the selected information should be organised and presented in an appropriate visualisation, e.g., table, narrative, or flowchart. That is considering the final application would help in selecting the best visualisation model. For example, tables might be more useful if the main

purpose is intervention identification whereas flowcharts might be more useful if the result will be shared with others.

6. Quality assessment: this is the final stage of the script elaboration process, and here the quality of the generated script is assessed. While a comprehensive list of criteria for assessing scripts could be considered, it is more effective to have a customised list based on the outcomes of the steps 2 and 3 about the applications' goals or information requirements.

6.2.4 Model validation

The developed framework was validated in the same way described in section 6.1.4 for validating the proposed crime scripting process model. The initial evaluation involved assessing whether any important activity was missing in the framework. This was accomplished by comparing the activities in the framework with the proposed crime scripting model and the essential activities in a goal-based approach. It was also assessed by checking whether there was no logical flaw in the framework and the order of the activities.

The framework was used by two scripters to develop crime scripts and its details were reviewed and tested. Some modifications were applied to the model at this stage, specifically where the order of *Choosing data source/collecting data* and *Reasoning whether the selected/collected data contain the required information* were swapped.

Finally, in a group discussion, it was argued whether i) the developed framework was an acceptable representation of crime scripting process, ii) it involves all the required activities for constructing a crime script from scratch, iii) no unnecessary activity seems to have been included, and iv) the organisation of the activities is reasonable.

Illustrative example

To provide a better understanding about the proposed framework and to test how it works in practice, it was used to construct some crime scripts. One of them, which regards stalking on Facebook, is described here as an illustrative example:

1. Problem definition

    - Definition of security/crime issue to be scripted: cyber-stalking is a growing and serious issue. In this crime event, an offender or offender(s) use the Internet or other electronic means to stalk or harass an individual, group, or organisation. Our concern is about stalking on Facebook (FB) where the offender creates a false identity, approaches their victim, gathers their information, and then misuses that information.

    - Description of why the crime-script-to-be is being developed and where it will be used: FB tasked a team of crime analysts to analyse this problem and identify possible ways of protecting its users against such a crime.

- Selection of the [candidate] prevention strategies for tackling the defined problem: FB is interested in a crime hardening strategy though other effective suggestions would be considered too.

2. Goal identification

- Identification of the crime script's [main] stakeholders and their goals and requirements: whilst there is potentially a wide range of stakeholders (e.g., victims, offenders, etc.), here, FB (the client) as the main stakeholder. The high-level goal of FB in this case is to prevent stalking. This can be further derived into the below goals:

  – to prevent account creation using fake/stolen identity,

  – to protect users' profiles from unauthorised access,

  – to protect users' personal information from malicious uses.

- Analysis of these goals by relating them to each other and also by relating them to the candidate prevention techniques: although this scripting process only focuses on those goals that are directly related to the selected application, there are some other goals that should be considered. For example FB's overall usability and revenue which is especially important if the selected scripting goals conflict with them as follows:

  Easy accessible service and *increased revenue* are both likely to be im-

portant goals for FB. However, they both likely conflict with the goal *to prevent account creation using fake/stolen identity*, as its prevention would require hard or further authentication when creating an account (against *easy accessible service*) and may dissuade or prevent new users (*increase revenue*). As such, this goal should be modified.

Considering the mentioned prevention strategy, *prevention* could also be replaced by a softer word, i.e. *hardening*, and the goal can be subsequently re-written as:

- hardening the process of creating account using fake/stolen identity.

- Selecting and finalising the goals. The three goals, discussed above, are about three separate stages of the crime process: opening an account, making a friend, and gathering information. They are clear, simple, independent, and do not [seem to] conflict. As such, all three are selected as the application goals.

3. Information requirements analysis: the goals of the current application are about the three main stages of the crime process to be scripted. As such, we need to have sufficient information about those three stages. This information should cover the activities of the main actors (e.g., offenders, victims, and FB), their behavioural patterns, and their skills (e.g., account creation, working with FB, stalking, etc.)

4. Data source selection/ data collection:

    - Choosing data source/collecting data: Here, existing data can be collected from FB, for example, FB tutorial/process description, FB cyberstalking incidents' reports, making friends on FB, etc.

    - Reasoning whether the selected/collected data contain the required information: It is likely the selected data sources cover the listed information requirements. Complementary data sources can also be searched later if required.

5. Script construction:

    - Selecting the required information: this step is conducted based on the listed information requirements. Three stages of the crime process were listed above. For each stage, relevant actors (e.g., victim, offender, FB, parents, etc.), and their relevant roles, activities, and skills are sought in the selected data.

    - Organising the elicited information and constructing crime script: the elicited information are organised, ordered, and presented in a table format, such that, as it can be easily used later for identifying possible interventions.

6. Quality assessment: three goals were identified in the 2^{nd} stage of the crime script development. Here, the written crime script is assessed based on those

three goals.

While different criteria could be considered for assessing the written script, this was only assessed using the *completeness* criterion. More specifically, it was discussed whether the generated script covers sufficient information about all the listed goals.

6.2.5 Discussion

The aim of this chapter was to develop a new goal-based crime scripting framework that offers a simple, clear, and structured approach to crime scripting. In order to develop this framework, first, a crime script process model was developed based on the activities that were observed in the existing crime scripting literature and in similar procedures in other works i.e. software engineering and business process modelling. The developed crime scripting process model is the first attempt to model activities in crime scripting, as explained in section 6.1.3.

Following this process model, and using information from two other fields (*requirements engineering* and *business process modelling*), a goal-driven crime scripting framework was developed which was presented in this section. The developed framework is one of the key contributions of this thesis. As described in this chapter, it provides a usable, clear, structured, and task-based approach for constructing crime scripts. Scripts developed using this framework are expected to have higher quality, especially in term of completeness, parsimony, and traceability criteria.

The developed framework could be assessed from different perspectives. In terms of the effectiveness of this method, and reasoning whether involving goals in the crime scripting process would improve the final scripts' quality, we can refer to the result of the experiment that was represented in chapter 5. These analyses (see later) suggest that informing scripters about the goals of their crime scripting task improves the quality of their final script in terms of how their content are related to the purpose of the crime scripting.

In terms of correctness, clarity, and usability, the framework was reviewed and tested by three experienced and independent crime scripters. The experts were satisfied with the clarity, usability, and completeness of the model. They all managed to develop their script and their final results were satisfactory.

For future work, the developed method can be compared against the existing crime scripting methods (e.g., Tompson & Chainey 2011). This can be done in various ways such as by conducting an experiment and using both methods to develop scripts and comparing the resulting scripts.

Chapter 7

Discussion

The aim of this thesis has been to explore the process of crime scripting including its applications and popularity, the methods used for this and their shortcomings, and to examine possible improvements of the process. The main issue of interest has been the mechanism of information selection as the key activity that shapes the contents of crime scripts. Each of the studies considered in the previous chapters concerned the step-by-step development of the conducted research. This chapter will begin by summarising the work in this thesis before moving on to discuss the key contributions of this work and the main opportunities for further development.

7.1 Summary

The work in this thesis has been motivated by the desire to contribute to the improvement of the crime scripting process. This crime modelling technique is essential in both practice (e.g., by security consultants and police practitioners) and

theory/technique development (e.g., by researchers). Indeed, a substantial number of studies have used crime scripting, and this number is rapidly growing. Crime scripting is a popular crime/attack modelling approach to conduct studies in a wide range of areas, e.g., cyber-security, money-laundering, violence, etc. However, as there exists very little information about 'how to construct a new crime script', the existing studies relying on intuitive or semi-intuitive in-house crime scripting methodologies. Because these scripting approaches do not have a detailed structure and/or are not systematic, they cannot be easily examined, replicated, or assessed. This means the quality of generated scripts is at best unknown; and at worst, questionable. This can be a serious issue. With a low-quality script, for example, it might not be possible to satisfy the requirements/goals of the application (e.g., effectively reducing crime). One method to improve this, which has been the focus of this thesis, is to upgrade the existing crime scripting processes to a more systematic and structured process.

The contributions of the thesis are both practical and theoretical. Several of the findings offer a tangible improvement to our understanding of the crime scripting process. These include the methods that have been used to construct crime scripts and their strengths and weaknesses. In particular, the thesis gives an up to date understanding of the current situation of crime scripting. Based on this, it highlights some of the issues of the current scripting practices and verifies the existance of these problems. In addition, a solution to improve the identified problems was suggested and explored through an experiment. Finally, based on the existing crime

scripting literature and similar methods and models from other fields, specifically goal-based methods, and business process modelling, a new structured goal-driven crime scripting framework was developed and presented using an illustrative example.

In more detail, Chapter 2 focused on the crime scripting process as found in the literature. It started by introducing the script-theoretic approach as an effective method to improve our understanding about the crime-commission process. That is, by revealing a step-by-step description of the activities that are conducted before, during, and after the crime process by the different actors that are involved. This model shows what is required for the offender to commit the crime including weaknesses in the environments and-or other actors' behaviour, the offenders' required skills and knowledge. Situational crime prevention (SCP) was also introduced in this chapter as the origin of crime scripts and one of its main applications. Then, this chapter discussed why the quality of crime scripts matters and how it affects how useful the scripts are for their users— e.g., how a crime reduction practitioner might not be able to determine a cost-effective and efficient prevention measure if they rely on low-quality crime scripts.

This chapter has also investigated how crime scripts are currently being developed. It was shown that existing crime scripting practices— which are mostly intuitive or semi-intuitive— suffer from various limitations. For example, the scripter's ability and choices (e.g., their previous experience of crime scripting and crime prevention, their cognitive skills, their personal interests and biases, and the assumptions

they would make) are amongst the main factors that might affect the quality of the final crime scripts. It was noted that these factors cannot be controlled or verified and so, it would not be possible to assess the quality of such scripts. As such, intuitive scripts cannot be automatically trusted as a good explanation of the crime process. Some other problems of existing scripting methods were also discussed in this chapter.

One of which was that they focus exclusively on crime prevention as their main goal and overlook other stakeholders' requirements. Another, and perhaps more importantly, is that they provide little or no help on how to develop scripts and how to identify relevant information for the scripts. Although there were some more structured approaches to producing crime scripts, they were highly customised and designed for very specific application and consequently were not generic enough to be suitably adapted to model any variety of crime problems.

The proposed solution to improve these problems was to develop a new goal-driven crime scripting method, which offers well-defined, easy to use, structured, and systematic crime scripting. This would therefore contribute to constructing high-quality scripts in terms of the goals of the script. This was one of the main contributions of this work and was represented in chapter 6. Before development of this method, three studies were completed which were presented in chapters 3, 4, and 5.

Chapter 3 provided a systematic review (SR) that took stock of current crime scripting studies. This review focused on the diffusion of the script-theoretic approach

(the number of crime scripts), the types of crimes that have been scripted, the scripting methods used by researchers, and the synonyms of crime scripts found in other fields. This literature review focused on the publications published in the 1994-2016 period that contain the keyword 'crime script(s)' or cited Cornish's seminal article. The results of this confirmed that the list of published crime scripts, whilst only representing a subset of all crime scripts, had grown exponentially since Cornish's article. It also showed that a wide range of crime types have been modelled using crime scripting techniques including cyberfraud, fraud, theft, terrorism, drug offences, environmental crime, sexual offences and other violent crime, trafficking, and firearms crime. Adding to the review that was presented in chapter 2, this chapter also highlighted that, despite the growing market for crime scripting approaches, still very little is known about the process of developing good quality scripts and suggested the need to develop structured crime scripting methodologies.

As explained in chapter 2, one of the main shortcomings of the existing crime scripting techniques is their dependency on the scripters' quality. This claim was based on the existing literature about intuitive methods. This problem in crime scripting was explored in chapter 4 which aimed to investigate the issue of variability in crime scripting. This investigation was conducted using data collected from 21 participants who watched an armed robbery incident as shown on a CCTV recorded video. The participants then independently wrote a crime script describing the crime commission process. The collected intuitive scripts were compared to each other, to better understand their similarities and differences. After introducing the chap-

ter's objectives, describing the method used to collect and code the scripts, and explaining the analysis used to compare the scripts, the results of the conducted comparisons were presented.

Chapter 4 developed and examined a method for comparing crime scripts produced by different analysts by statistically characterising their similarities and differences. The application of this method to a set of robbery scripts confirmed that different individuals produce scripts of varying quality thereby evidencing the limit of an intuitive approach to crime scripting. It therefore also confirmed the need for a more structured and systematic crime scripting technique (e.g., a goal-driven script elaboration) that could reduce the observed variance in quality. This chapter also highlighted some other benefits that would be expected from such an approach such as potentially greater confidence in the constructed scripts which could encourage more scripters to publish their scripts and therefore build up the knowledge base around crime scripts in different applications. Other potential benefits also include assisting/training scripters to better identify the relevant information for their specific application and evaluating the quality of their scripts.

One thing that was repeatedly mentioned in previous chapters was this suggestion that the *development of a goal-driven crime scripting approach* might help scripters in building higher quality scripts. Even though more structured crime scripting methodologies might address the problems discussed in the previous chapters, a possible criticism is that the benefit of *goal-driven* methods (as a possible option) is questionable. Chapter 5 examined this criticism and represented an experiment

to study the effects of scripters' knowledge of [crime script application's] goals in their information selection practice. A hypothesis was drawn and statistically tested in this examination using data from one hundred and thirty volunteers took part in this experiment. In more detail, each participant wrote a crime script for a given crime event: *a bank card theft incident*. They were provided with the same data and experimental environment, though they were given different script application purposes. From this, one hundred and twenty-four crime scripts were collected, which were coded using the classification system described in chapter 4. This resulted in an *aggregated script* that contained the information from all of the scripts. To test the hypothesis, the relationship between each step in the aggregated script and the *goals* given to the scripters was analysed. This was measured based on a selection of experts' opinion where those experts decided whether a given step should be considered as relevant to a given application goal or not.

The result of this experiment suggested that informing scripters about goals would improve the crime scripts' content with regards to having more related information that can contribute in identifying SCP measures. It also suggested a more structured, goal-driven crime scripting method would result to more complete script— regarding the scripts application goal— that would benefit situational crime prevention practices.

Chapter 6 describes the development of a goal-driven crime scripting framework that could provide scripters with a better understanding about the crime scripting process (e.g., activities that should be followed in constructing scripts, and how to

undertake them) which should improve the resulting scripts. This chapter started by introducing a crime scripting process model that was developed based on the crime scripting activities identified in the systematic review. Based upon the *crime scripting process model*, *goal-driven techniques* from *requirements engineering*, and *business process modelling*, a *goal-driven crime scripting framework* was developed and examined. This framework provided a step by step procedure of the activities that should be followed to develop a script; from *defining problem* to *evaluating the generated scripts*. The presented model was then assessed by three experts. The goal-driven model was also described using an illustrative example. It was determined based on these experts that the presented goal-based crime scripting framework offered a usable, clear, structured, and task-based approach for constructing crime scripts and scripts developed using this framework are expected to have higher quality, especially in term of completeness, parsimony, and traceability.

7.2 Unifying themes

Although the points arising within the topics studied have been discussed at the end of each chapter, a number of more general themes emerge when considering the body of work as a whole. These are examined and recapped in this section.

Crime scripts are increasingly popular: some published works (e.g., Ekblom & Gill 2016, Leclerc 2017) suggested that crime scripting has increased in recent years, however, no empirical evidence was provided to support their claim. The original research presented in chapter 3 demonstrated this growth, especially in the last

10 years. Furthermore, while crime scripts are increasingly popular within criminology, interestingly, they are also so in other disciplines. A wide range of security and crime related studies have used crime scripting in their analysis for different purposes [or applications] such as *pinch-points identification* [to apply SCP measures], *risk analysis*, *decision-making*, and *policy-making* and to tackle different types of crime and security problems e.g., cyber-crime, fraud, theft, terrorism, drugs offences, environmental crime, sexual offences, trafficking, violent crime, and firearms crime.

Crime script are easy to develop and use: from the work in this thesis it is clear there are a number of reasons for this sharp growth. In particularly:

- Crime scripts are easy to understand (this is actually one of the main reasons for scripting crime i.e. to improve our understanding about a crime [or security related] event) and easy to develop (people can easily look at already published scripts and use them as a pattern, use their intuition to interpret their available data, and organise their perceived information to construct a script), and

- Crime scripts are handy and effective; they do not offer new information, but can present the available information in a detailed, clear, concise, and understandable form. They can also give a simple description of the process and assist the analysis and boost the chance of identifying effective [SCP] resolutions.

A crime script is not necessarily a quality script: crime scripts can be developed using only scripters' intuition. While intuitive methods have their own advantages, e.g., they do not require any training, need minimum resources, and have low cost of development (e.g., time), they also have serious shortcomings. The content and consequently the quality of intuitive scripts can vary substantially and too much depends on the scripter including their experience, knowledge, interests, etc. No matter the application of a crime script, their success to a degree depends on the quality of the crime script. For example, a poor crime script may provide the wrong or insufficient understanding of the crime process and so can result in the poorer performance of any application of that script e.g., the SCP measure.

Why to choose systematic not intuitive crime scripting: unlike intuitive and ad hoc approaches, systematic methods are built based on well-defined and examined procedures. These, in principle should generally result in better quality products compared to alternatives (i.e. intuitive approaches). Systematic products also should not vary as much as intuitive ones and not depend on the scripters' ability. In effect, the final scripts should also be reproducible by independent developers.

So, applying the same logic to crime scripts, it can be implied that systematically generated crime scripts do not have the same shortcomings of intuitive products as mentioned above. This thesis has examined this matter in two ways. Firstly, chapter 4 investigated the limitations of the intuitive approach to crime scripting and showed that intuitive scripts generated by different scripters can vary and can also lack the required quality. Secondly, chapter 5 further explored the crime scripting process

in terms of the informing of crime scripters about the purpose of their given scripts. The results of this exploration suggests that the content of scripts can be affected by this.

Has any structured crime scripting been developed, yet? Based on the reviews presented in chapters 2 and 3, it seems the intuitive approach is the most popular current crime scripting practice. There are some semi-structured crime scripting methodologies e.g., the universal script or the template method, however, they were developed intuitively and for very specific applications.

What are the activities in a crime scripting process? The conducted reviews found no study that specifically listed details of the activities that should be followed for developing crime scripts. As shown in chapter 6, this thesis has elicited the crime scripting related activities from the literature. These activities have then been refined, organised, and presented as a crime script process model. This model is the first attempt of its kind and can be considered as the basis for any crime scripting approach.

7.3 Impact and future work

The findings of the thesis offer an improvement in our understanding of a crime scripting, its process, and its limitations and establish a new framework for scripting crime. These include a comprehensive and up-to-date reference for researchers and practitioners who would like to develop, use, or study crime scripts from differ-

ent fields of studies and for different purposes such as identification of situational prevention measures, policy-making, and security/crime management.

The goal-driven crime scripting framework that was introduced in this thesis was tested and validated by a small number of the experts in the fields. However, this needs further verification and exploitation and any advantages of this approach needs to be corroborated in future studies. In particular, more robust validation can be performed to test different aspects of this framework. For example, and firstly, using the proposed framework on a few real and comprehensive case studies that involve multiple goals. Secondly, by running an experiment to assess different aspects of this framework e.g., its usability (questioning whether its clarity, simplicity, effectiveness etc. are in an acceptable level based on its users' opinion) or performance (analysing the scripts generated using this framework to assess how it contributes in constructing quality scripts).

Also, and whilst the proposed approach should help the development of crime scripts, one potential issue, still in the proposed methodology, is that scripters are currently develop their script using the general but limited software tools available to them e.g., MS Word. A crime scripting software tool can be developed that help scripters in different steps of their work such as problem definition, data acquisition, organising script's steps, and evaluating their script. Such a tool can also provide some tutorials and guidelines, which is especially helpful for those who are new to crime scripting.

Moreover, the experiment that was presented in chapter 5 focused on completeness of goal-based crime scripts. Conducting further research to assess the effect of goals on other quality criteria of scripts such as parsimony or traceability would be useful.

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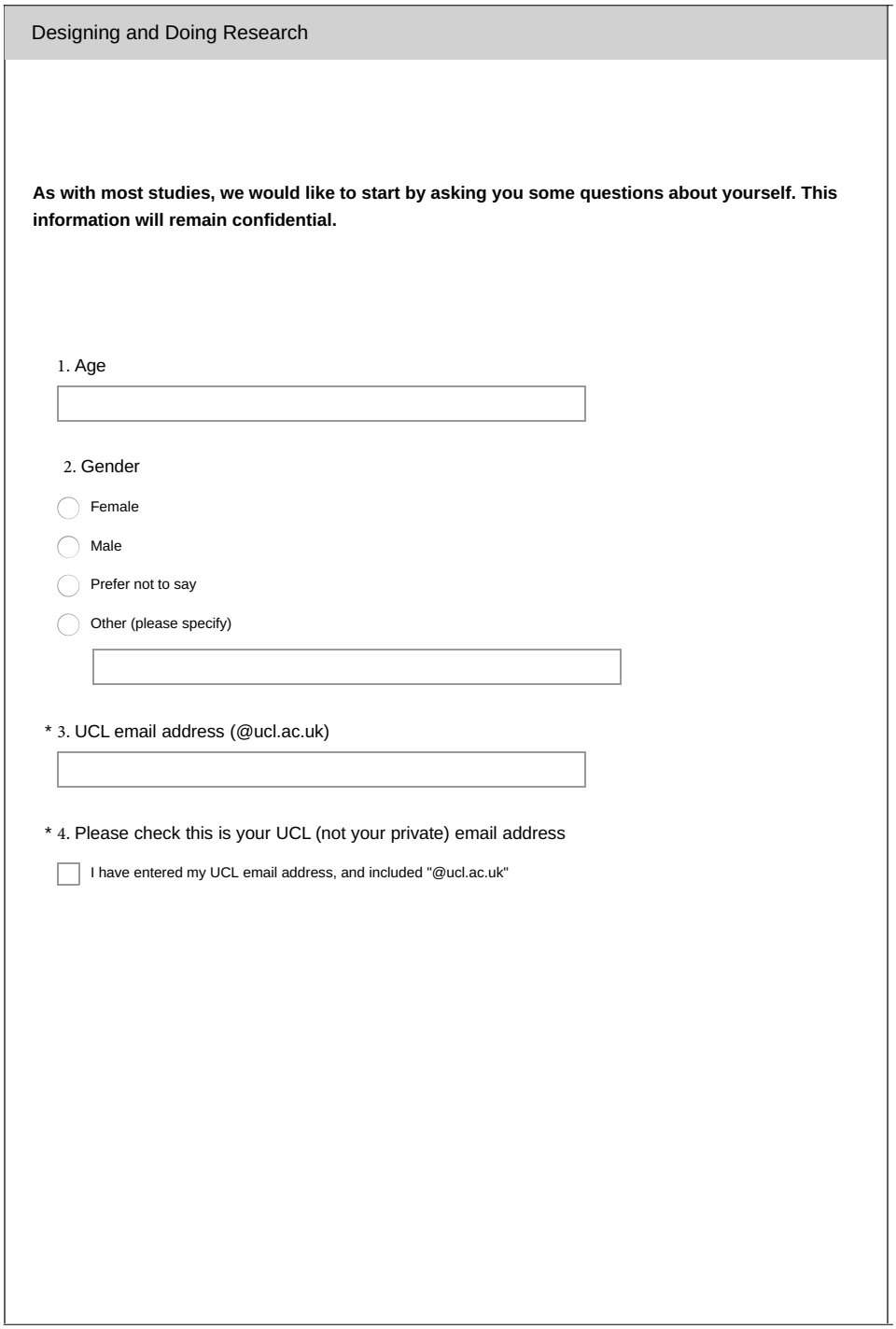
Appendix A

A sample of the questionnaire used for enrolling volunteers in the experiment


Designing and Doing Research

As with most studies, we would like to start by asking you some questions about yourself. This information will remain confidential.

1. Age

2. Gender

- Female
- Male
- Prefer not to say
- Other (please specify)

* 3. UCL email address (@ucl.ac.uk)

* 4. Please check this is your UCL (not your private) email address

- I have entered my UCL email address, and included "@ucl.ac.uk"

Figure A.1: Preliminary questionnaire (1/3)

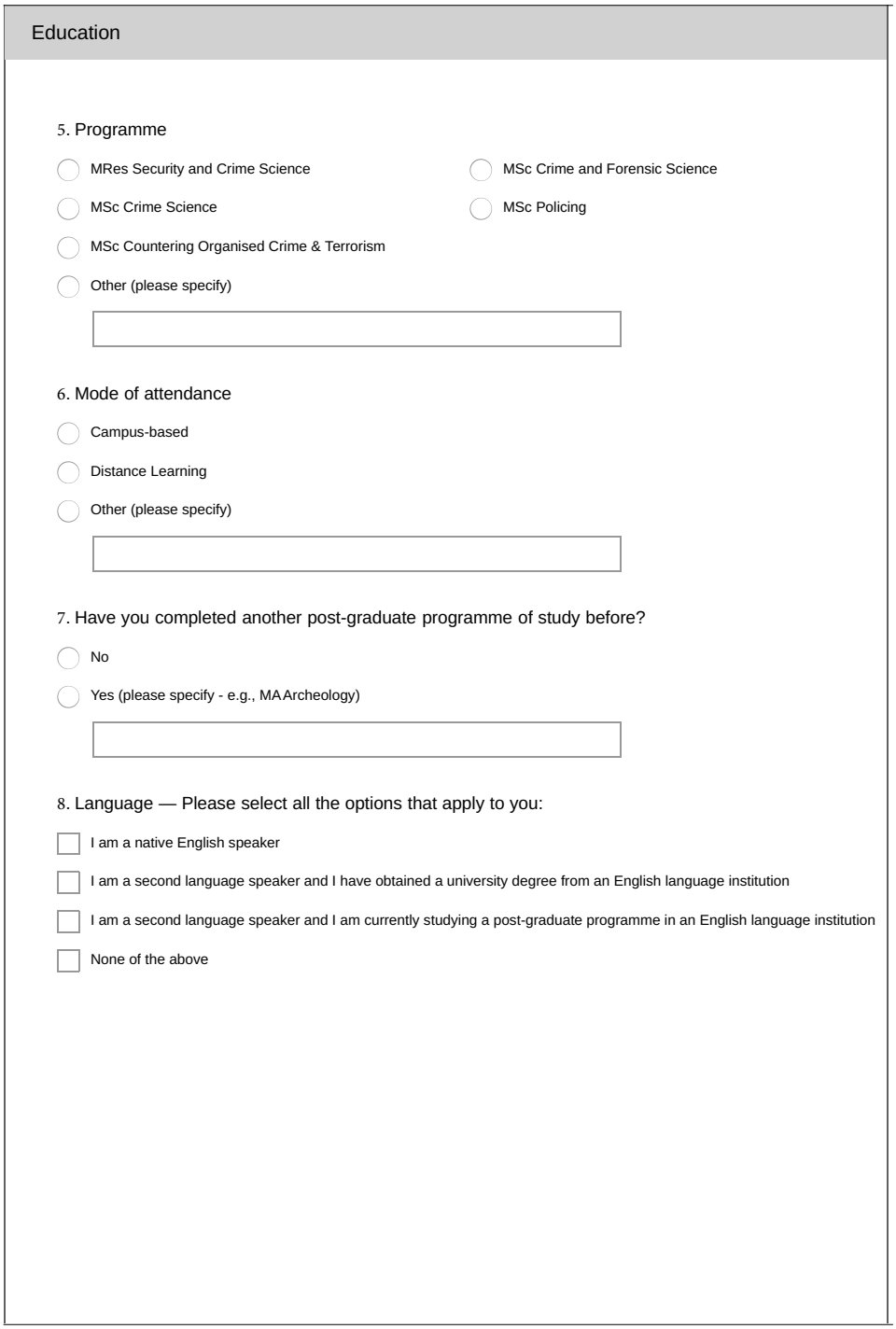
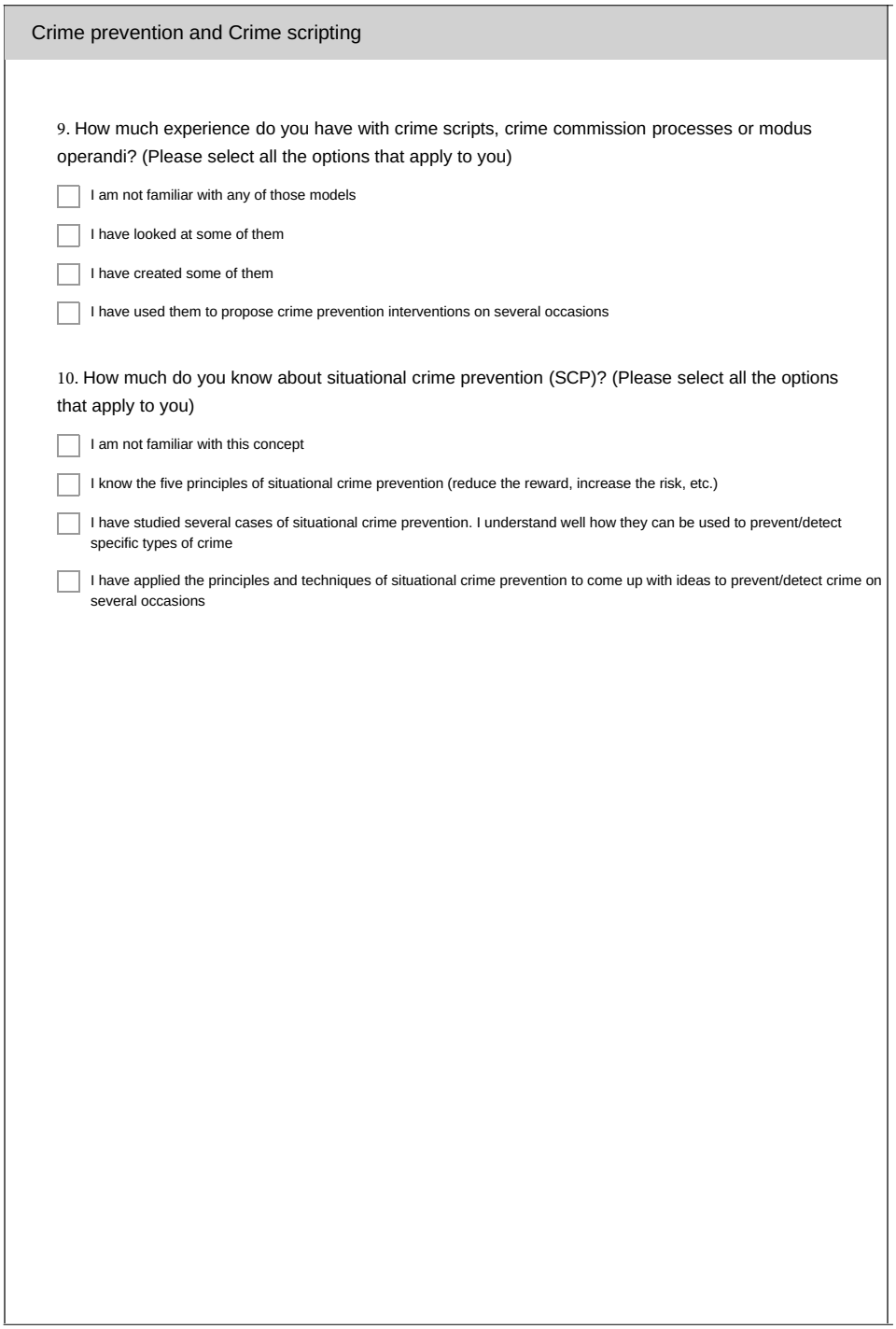


Figure A.1: Preliminary questionnaire (2/3)



Crime prevention and Crime scripting

9. How much experience do you have with crime scripts, crime commission processes or modus operandi? (Please select all the options that apply to you)

- [ ] I am not familiar with any of those models
- [ ] I have looked at some of them
- [ ] I have created some of them
- [ ] I have used them to propose crime prevention interventions on several occasions

10. How much do you know about situational crime prevention (SCP)? (Please select all the options that apply to you)

- [ ] I am not familiar with this concept
- [ ] I know the five principles of situational crime prevention (reduce the reward, increase the risk, etc.)
- [ ] I have studied several cases of situational crime prevention. I understand well how they can be used to prevent/detect specific types of crime
- [ ] I have applied the principles and techniques of situational crime prevention to come up with ideas to prevent/detect crime on several occasions

Figure A.1: Preliminary questionnaire (3/3)

Appendix B

Training materials for learning about crime scripts and crime scripting

UCL

Crime Scripting

Hashem Dehghanniri

UCL

Script

A **script** is a structure that describe **sequence of events** in a particular context.

This script describes the activities performed by a customer in a restaurant.

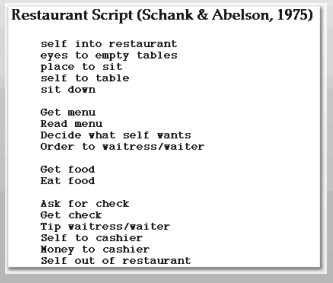


Figure B.1: Crime scripting (1/9)

UCL

Script

Scripts can also be used to:

- show **how offenders commit a crime**, and
- inform the **identification** of:
  - **pinch points** and
  - **interventions**.

UCL

Crime script

A crime script is a **step-by-step** description of the **actions** involved in **committing specific crimes**.

Crime scripts can be used to organise knowledge about the requirements of crime commission such as the:

- **Actors**
- **Actions and Decisions**
- **Places**
- **Resources and Skills**
- **Other situational factors** influencing the actions

Figure B.1: Crime scripting (2/9)

UCL

Crime script: auto theft

This crime script describes how an offender steals an automobile.

Step No	Steps
1	**Offender** gathers tools
2	**Offender** enters parking lot
3	**Offender** loiters unobtrusively
4	**Offender** selects vehicle
5	**Offender** approaches vehicle
6	**Offender** breaks into vehicle
7	**Offender** takes vehicle
8	**Offender** reverses out of bay
9	**Offender** leaves parking lot

UCL

Crime script components

Crime scripts include various components such as:

- **Actors:** offender, victim, bystander, guardian, …
- **Actions/Decisions:** walks, threatens, flirts, says, …
- **Places:** shop, Amazon, bus station, …
- **Resources** that offenders deployed to commit crime: gun, money, spy software, …
- **Skills** that offenders deployed to commit crime: knowing how to gain trust, knowing how to apply online for a credit card, …

As well as:

- The **order** in which different steps are executed.

Figure B.1: Crime scripting (3/9)

UCL

Crime script: auto theft

Crime script **must** have one or more "actors".

Each step **must** have a specific "actor".

Step No	Steps
1	**Offender** gathers tools
2	**Offender** enters parking lot
3	**Offender** loiters unobtrusively
4	**Offender** selects vehicle
5	**Offender** approaches vehicle
6	**Offender** breaks into vehicle
7	**Offender** takes vehicle
8	**Offender** reverses out of bay
9	**Offender** leaves parking lot

UCL

Crime script: auto theft

Each step **must** have a specific "action".

Crime script **may** include one or more "decisions".

Step No	Steps
1	**Offender** gathers tools
2	**Offender** enters parking lot
3	**Offender** loiters unobtrusively
4	**Offender** selects vehicle
5	**Offender** approaches vehicle
6	**Offender** breaks into vehicle
7	**Offender** takes vehicle
8	**Offender** reverses out of bay
9	**Offender** leaves parking lot

Figure B.1: Crime scripting (4/9)

UCL

Crime script: auto theft

Crime script **may** include one or more "resources/tools".

Crime script **may** include one or more "places".

Step No	Steps
1	**Offender** gathers tools
2	**Offender** enters parking lot
3	**Offender** loiters unobtrusively
4	**Offender** selects vehicle
5	**Offender** approaches vehicle
6	**Offender** breaks into vehicle
7	**Offender** takes vehicle
8	**Offender** reverses out of bay
9	**Offender** leaves parking lot

UCL

Crime script: auto theft

Crime script **may** include one or more "skills".

The steps **must** be chronologically ordered.

Step No	Steps
1	**Offender** gathers tools
2	**Offender** enters parking lot
3	**Offender** loiters unobtrusively
4	**Offender** selects vehicle
5	**Offender** approaches vehicle
6	**Offender** breaks into vehicle
7	**Offender** takes vehicle
8	**Offender** reverses out of bay
9	**Offender** leaves parking lot

Figure B.1: Crime scripting (5/9)

UCL

Crime script: computer abuse

This crime script describes how an offender takes control of someone else's computer and misuse it.

Step No	Steps
1	Offender already has access to the organisation as an employee
2	Offender waits for the accountant to leave the office
3	Accountant leaves his computer without signing out
4	Offender accesses accountant's computer
5	Offender accesses "cheque printing" software
6	Offender enters cheque details (amount, date, and payee name)
7	Offender prints the cheque
8	Offender takes the cheque
9	Offender removes the evidence of wrong doing
10	Offender leaves the office
11	Offender goes to a bank branch
12	Offender caches in the cheque

UCL

Writing a crime script

A script should describe the sequence of activities performed by or affecting the offender and other relevant parties before, during, and after the crime event.

- Scripts can span a long period of time – starting before the main crime event and continuing after it – this can inform crime reduction efforts.

Figure B.1: Crime scripting (6/9)

UCL

Crime script: computer abuse

This script starts by some activities before the main crime event and continuing after it.

Step No	Steps
1	Offender already has access to the organisation as an employee
2	Offender waits for the accountant to leave the office
3	Accountant forgets to sign out from his/her computer
4	Offender accesses accountant's computer
5	Offender accesses "cheque printing" software
6	Offender enters cheque details (amount, date, and payee name)
7	Offender prints the cheque
8	Offender collects the cheque
9	Offender vanishes the traces
10	Offender leaves the computer
11	Offender cashes the cheque
12	Offender spends the money

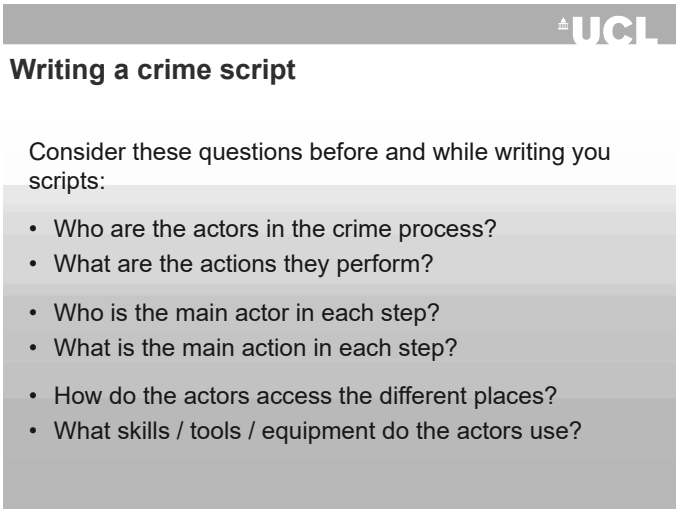
UCL

Crime script: computer abuse

This script includes various activities that are performed by or affecting the offender.

Step No	Steps
1	Offender already has access to the organisation as an employee
2	Offender waits for the accountant to leave the office
3	Accountant forgets to sign out from his/her computer
4	Offender accesses accountant's computer
5	Offender accesses "cheque printing" software
6	Offender enters cheque details (amount, date, and payee name)
7	Offender prints the cheque
8	Offender collects the cheque
9	Offender vanishes the traces
10	Offender leaves the computer
11	Offender cashes the cheque
12	Offender spends the money

Figure B.1: Crime scripting (7/9)



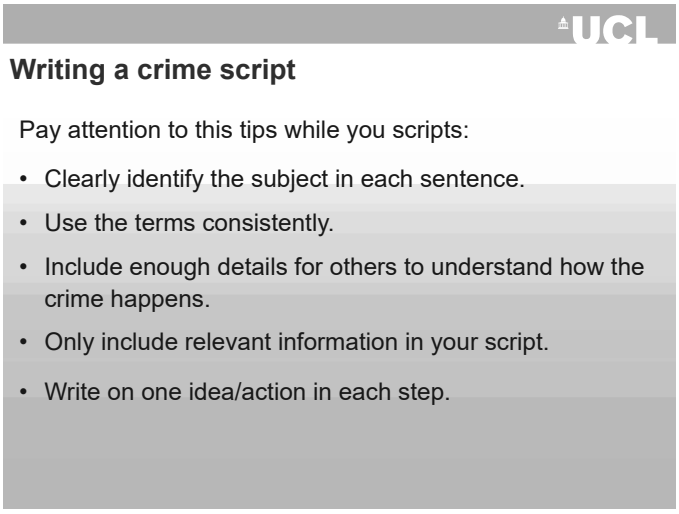


Figure B.1: Crime scripting (8/9)

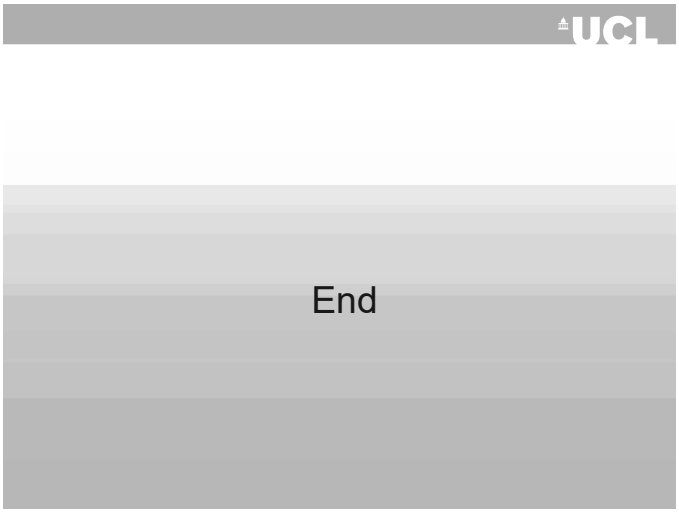


Figure B.1: Crime scripting (9/9)

Appendix C

Crime scripting test

Crime Scripting — Test

Welcome!

Component 3 > Phase 1 > Task 1: This 30 minute test was designed to check that you understand the basic concepts of crime scripting. You must watch the video "Crime Scripting: A practical introduction" on Moodle (6 mins) before doing the test: https://moodle.ucl.ac.uk/mod/lti/view.php?id=3180473

Please note you will not be able to change your answers once you leave a page.

Crime Scripting — Test

Questions

Please answer the following questions:

Figure 1:

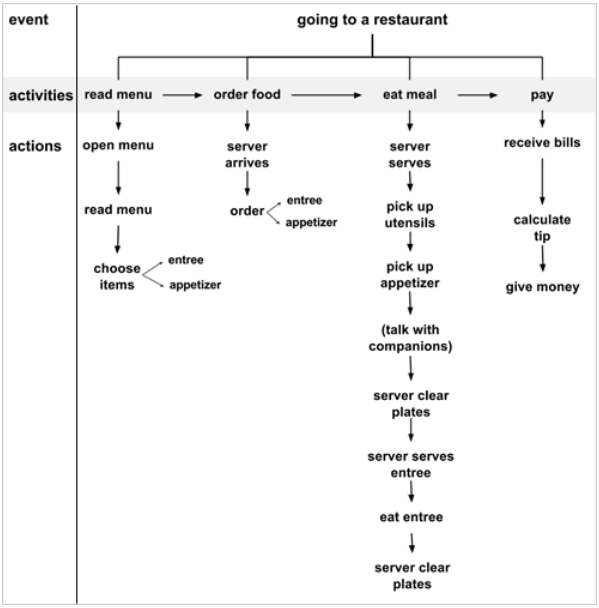


Figure C.1: Crime scripting test (1/8)

1. Which statement about Figure 1 is correct?

- ◯ This is a simple script—there is no crime event here.
- ◯ This is an example of a restaurant crime script.
- ◯ This is neither a crime script nor a script

Crime Scripting — Test

Answers

Question 1: Which statement about Figure 1 is correct?
Answer: This is a simple script—there is no crime event here.

Crime Scripting — Test

Questions

Table 1:

Step No	Steps
1	Offender has access to the organisation as an employee
2	Offender waits for the accountant to leave the office
3	Accountant leaves his computer without signing out
4	Offender accesses accountant's computer
5	Offender accesses "cheque printing" software
6	Offender enters cheque details (amount, date, and payee name)
7	Offender prints the cheque
8	Offender takes the cheque
9	Offender removes the evidence of wrong doing
10	Offender leaves the office
11	Offender goes to a bank branch
12	Offender caches in the cheque
13	Offender exists the bank branch

Figure C.1: Crime scripting test (2/8)

2. Tick all correct statements about Table 1:

- [ ] This is a crime script.
- [ ] This crime script is visualised using a table.
- [ ] This is not a crime script.
- [ ] The “offender” is the only actor mentioned in this script.
- [ ] None of the above is correct.

Crime Scripting — Test

Answers

Question 2: Tick all correct statements about Table 1:

Correct: This is a crime script.
Correct: This crime script is visualised using a table.
Incorrect: ~~This is not a crime script.~~
Incorrect: ~~The “offender” is the only actor mentioned in this script.~~
Incorrect: ~~None of the above is correct.~~

Crime Scripting — Test

Questions

3. Which of the below statements about crime scripts are correct?(select all applicable)

- [ ] The order of the steps is not very important; the steps can be organised in any order.
- [ ] Crime scripts are used to analyse crime commission processes (actions, decisions, and situational factors) to identify pinch points and intervention for disrupting the crime process.
- [ ] Crime scripts can be used to show how offenders commit a given type of crime.
- [ ] There is no need to have a specific actor in each step.
- [ ] Crime scripts can be used to identify changes in the environment that could prevent a specific type of crime.
- [ ] None of the above is correct.

Crime Scripting — Test

Answers

Figure C.1: Crime scripting test (3/8)

Question 3: Which of these statements about crime scripts are correct? (select all applicable)

Incorrect: ~~The order of the steps is not very important; the steps can be organised in any order.~~
Correct: Crime scripts are used to analyse crime commission processes (actions, decisions, and situational factors) to identify pinch points and intervention for disrupting the crime process.
Correct: Crime scripts can be used to show how offenders commit a given type of crime.
Incorrect: ~~There is no need to have a specific actor in each step~~.
Correct: Crime scripts can be used to identify changes in the environment that could prevent a specific type of crime.
Incorrect: ~~None of the above is correct.~~

Crime Scripting — Test

Questions

Table 1:

Step No	Steps
1	Offender has access to the organisation as an employee
2	Offender waits for the accountant to leave the office
3	Accountant leaves his computer without signing out
4	Offender accesses accountant's computer
5	Offender accesses "cheque printing" software
6	Offender enters cheque details (amount, date, and payee name)
7	Offender prints the cheque
8	Offender takes the cheque
9	Offender removes the evidence of wrong doing
10	Offender leaves the office
11	Offender goes to a bank branch
12	Offender caches in the cheque
13	Offender exists the bank branch

Figure C.1: Crime scripting test (4/8)

4. Select the *component types* for these items:

	Component types
Access	
Accountant's computer	
Access "cheque printing" software	
Cheque printing software	
Collects the cheque	
Computer	
Employee	
Enters cheque details	
Leaves	
Offender	
Prints the cheque	
Remove evidence of wrongdoing	
Signing out	
The accountant	
The office	
Waits	

Crime Scripting — Test

Answers

Figure C.1: Crime scripting test (5/8)

Question 4: Read Table 1 again and select the component types for the below items:
Answer:
Access is an action.
Accountant's computer is a resource or tool.
Access "cheque printing" software is an action.
Cheque printing software is a resource or tool.
Collects the cheque is an action.
Computer is a resource or tool.
Employee is an actor.
Enters cheque details is an action.
Leaves is an action.
Offender is an actor.
Prints the cheque is an action.
Remove evidence of wrongdoing
Signing out is an action.
The accountant is an actor.
The office is a place.
Waits is an action.

Crime Scripting — Test

Questions

5. An actor can be:

- ☐ A person — for example: "offender", "victim", "bystander", "employee", or "Charlie" (name of a person).
- ☐ A system that triggers important events in the crime process— for example printing software or authentication system.
- ☐ A passive object in a crime scene — for example a tree or a chair.
- ☐ An autonomous machine that triggers important events in the crime process — for example an autonomous vehicle.

Crime Scripting — Test

Answers

Question 5: An actor can be:

Correct: A person — for example: "offender", "victim", "bystander", "employee", or "Charlie" (name of a person).
Correct: A system that triggers important events in the crime process— for example printing software or authentication system.
Incorrect: A passive object in a crime scene — for example a tree or a chair.
Correct: An autonomous machine which interact with crime process — for example an autonomous vehicle or a smart lock.
Incorrect: An autonomous machine that triggers important events in the crime process — for example an autonomous vehicle.

Crime Scripting — Test

Figure C.1: Crime scripting test (6/8)

Questions

6. Modelling the actions in the computer abuse crime script can help analysts identify the skills that offender needed to commit the crime?

- ◯ Yes.
- ◯ No.

Crime Scripting — Test

Answers

Question 6: Modelling the actions in the computer abuse crime script can help analysts identify the skills that offender needed to commit the crime?

Yes, that's correct.

Crime Scripting — Test

Writing a Crime Script

To conclude the test, we will now ask you to write a crime script for the crime event represented in the video (below). To write your crime script:

- **start each step with an actor's name (e.g., Offender selects a victim OR ANPR (automatic number-plate recognition system identifies the number plate of the car).**
- **make sure each step covers only one action,**
- **make sure there is a logical flow between the steps,**
- **make sure each step has a specific actor.**

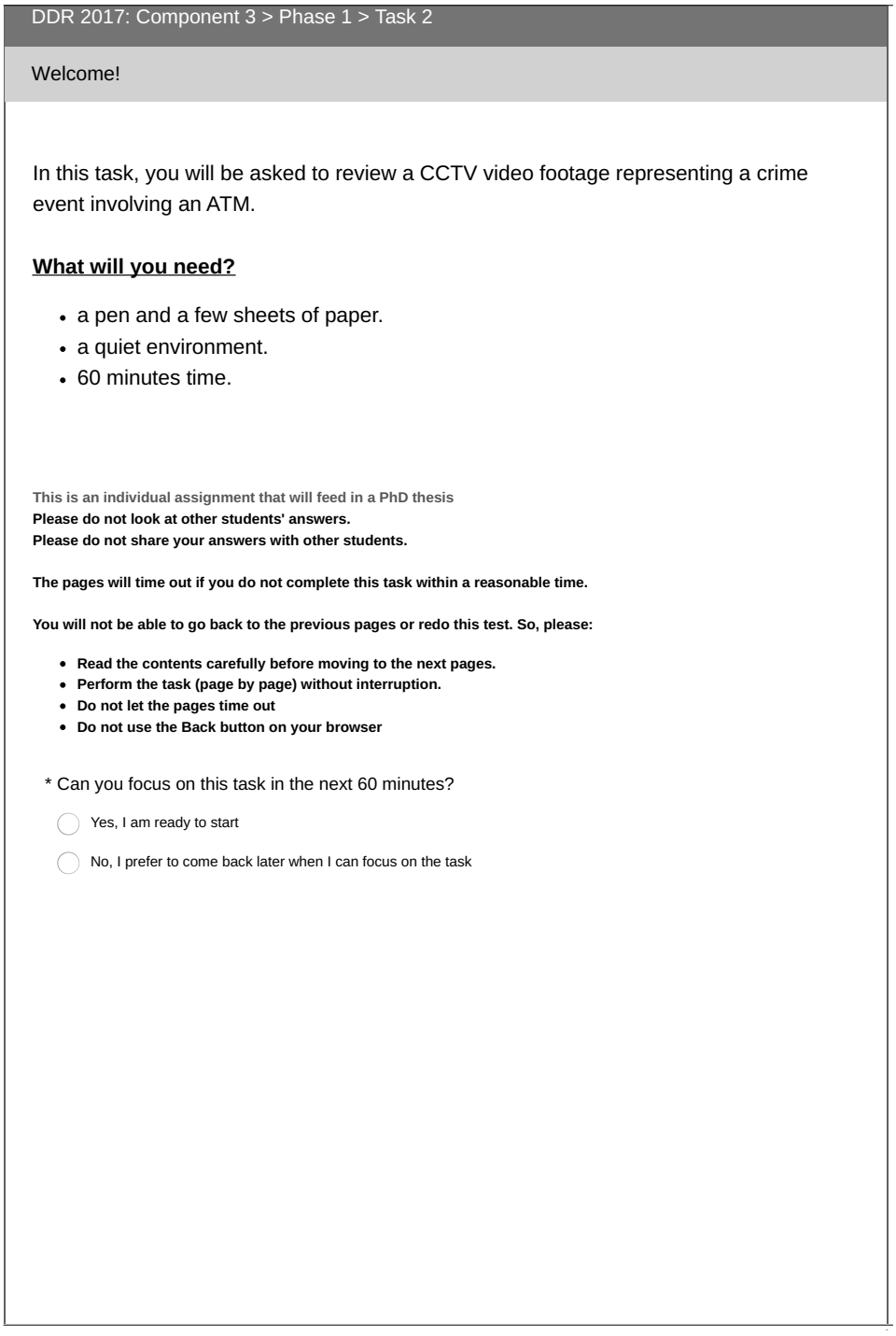
Figure C.1: Crime scripting test (7/8)

7. Write your script here:

Figure C.1: Crime scripting test (8/8)

Appendix D

An example of bank card theft experiment task


DDR 2017: Component 3 > Phase 1 > Task 2

Welcome!

In this task, you will be asked to review a CCTV video footage representing a crime event involving an ATM.

What will you need?

- a pen and a few sheets of paper.
- a quiet environment.
- 60 minutes time.

This is an individual assignment that will feed in a PhD thesis
Please do not look at other students' answers.
Please do not share your answers with other students.

The pages will time out if you do not complete this task within a reasonable time.

You will not be able to go back to the previous pages or redo this test. So, please:

- **Read the contents carefully before moving to the next pages.**
- **Perform the task (page by page) without interruption.**
- **Do not let the pages time out**
- **Do not use the Back button on your browser**

* Can you focus on this task in the next 60 minutes?

Yes, I am ready to start

No, I prefer to come back later when I can focus on the task

Figure D.1: An example of bank card theft experiment task (1/10)

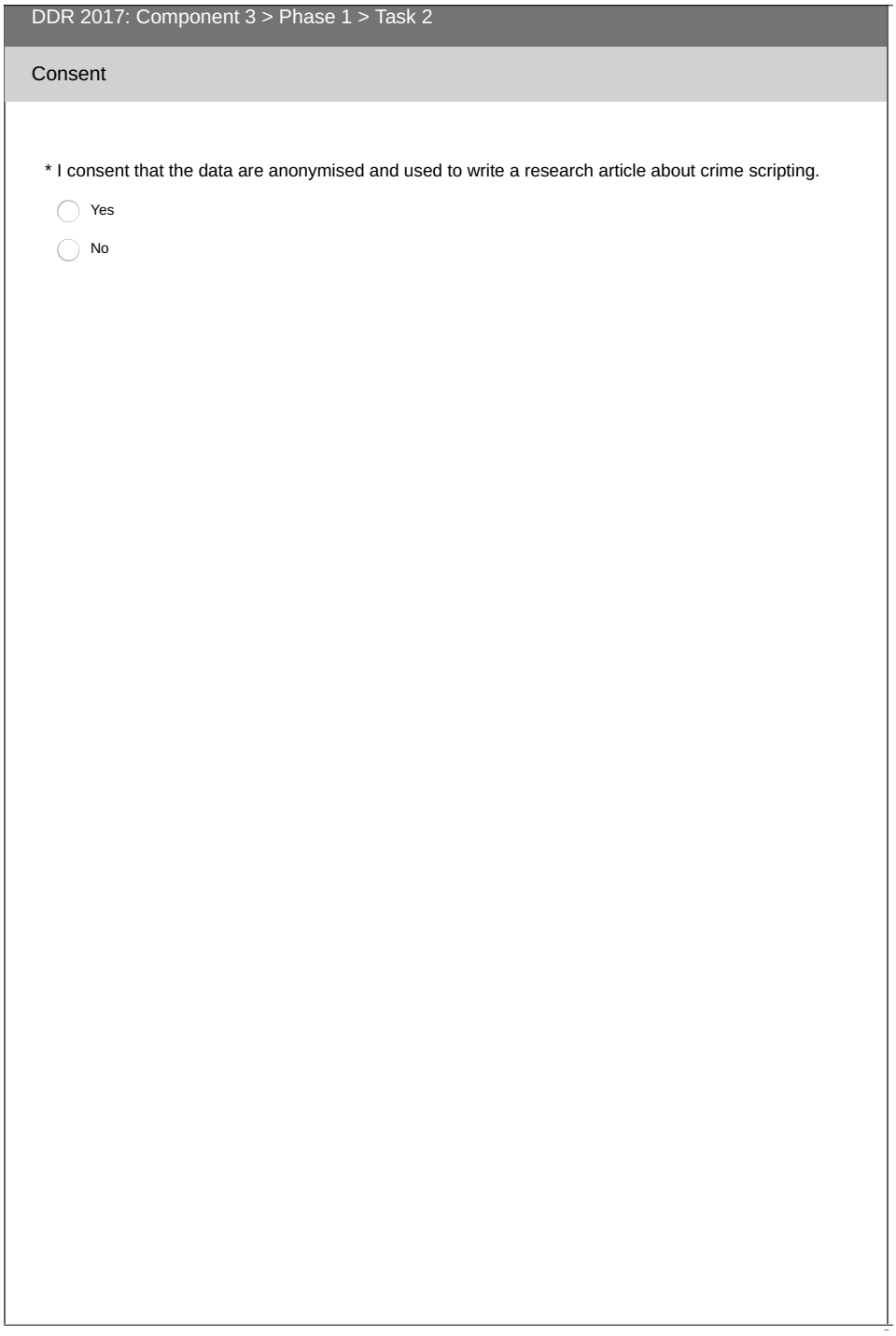


Figure D.2: An example of bank card theft experiment task (2/10)

DDR 2017: Component 3 > Phase 1 > Task 2

ATM crime

Over the last few years, a number of crimes have happened at UK bank branches. Using the same modus operandi, offenders have committed the same crime against a large number of victims.

A consortium of banks have consulted security experts about it, and they concluded that the most promising solution to the problem would be to **redesign the Automated Teller Machines** (ATMs) **to make it more difficult for offenders to commit the crime.**

Figure D.3: An example of bank card theft experiment task (3/10)

DDR 2017: Component 3 > Phase 1 > Task 2

ATM Design and Security Risks

Your company has been contracted to redesign ATMs, so it is more difficult for offenders to exploit their vulnerabilities. You have been tasked to draw a list of recommendations for the design of the new ATMs.

To perform your task:

1. **Watch the video below (you can pause, replay, and go backward/forward as many times as you need). It represents a crime captured by a CCTV system at a Natwest branch (~1 minute).**
2. **Identify specific vulnerabilities in the existing Automated Teller Machines (ATMs) that were exploited by offenders,**
3. **Come up with ideas for the design of ATMs so offenders would not be able to commit this crime**
4. **Then, write your suggestions in the box below:**

Figure D.4: An example of bank card theft experiment task (4/10)

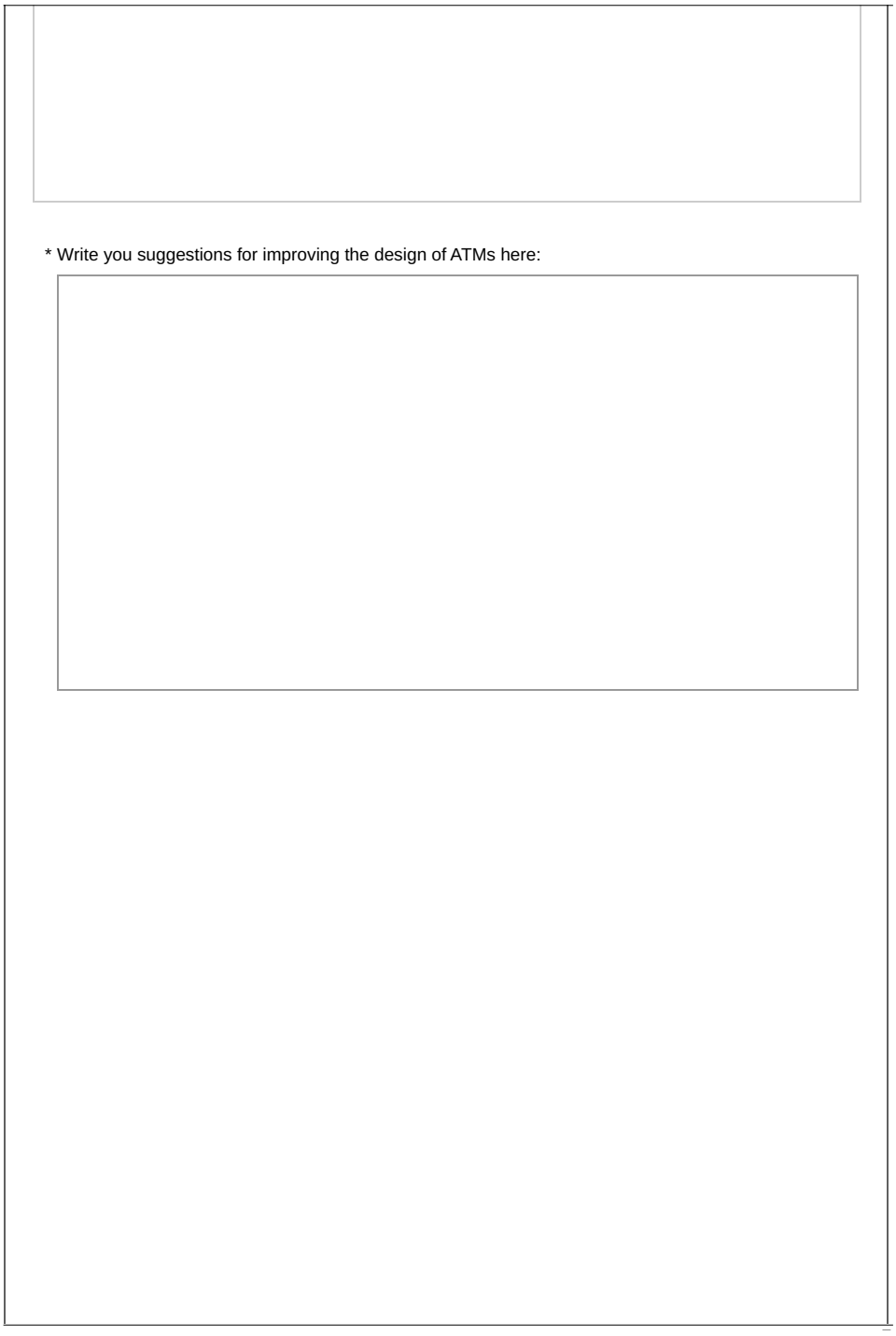


Figure D.5: An example of bank card theft experiment task (5/10)

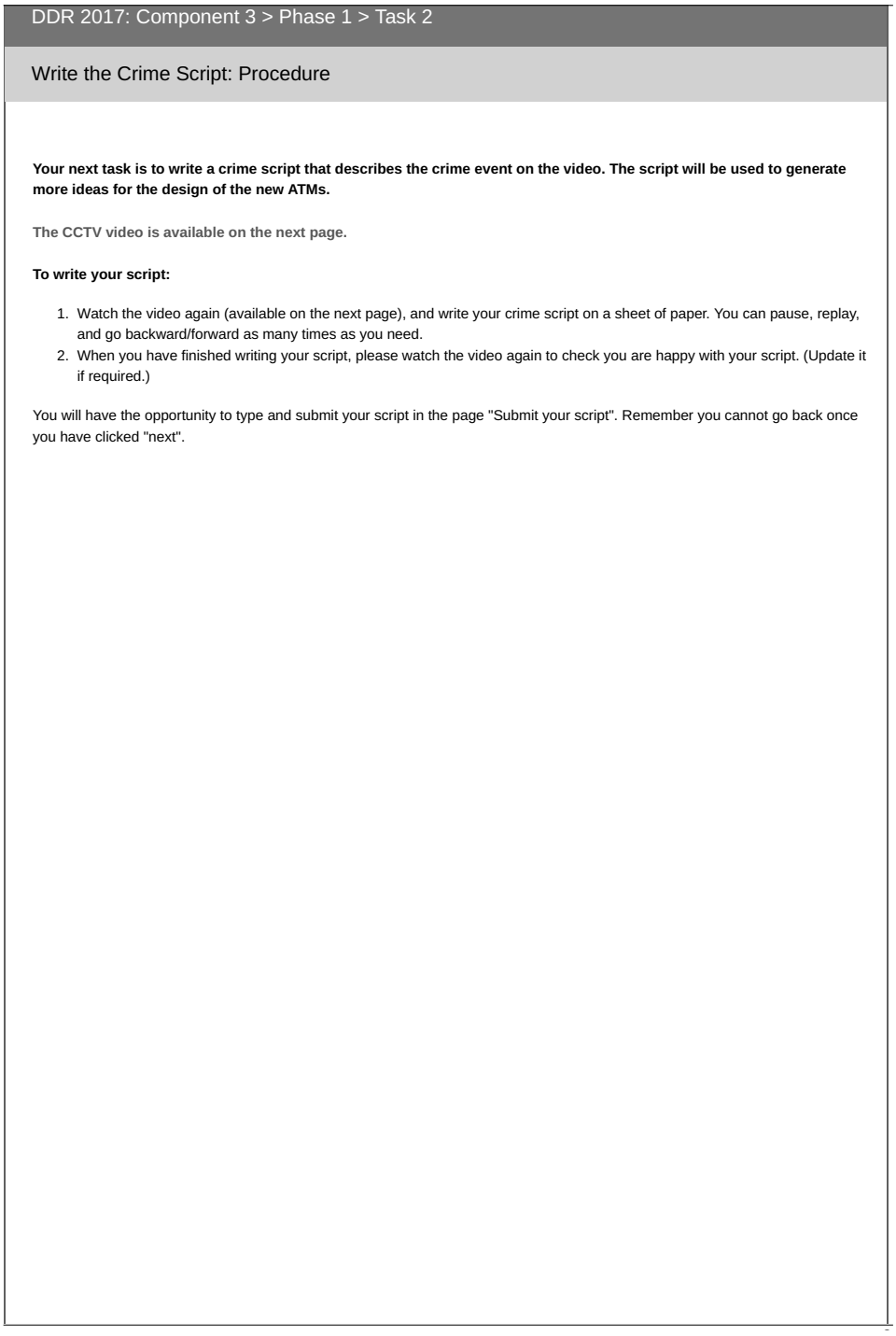


Figure D.6: An example of bank card theft experiment task (6/10)

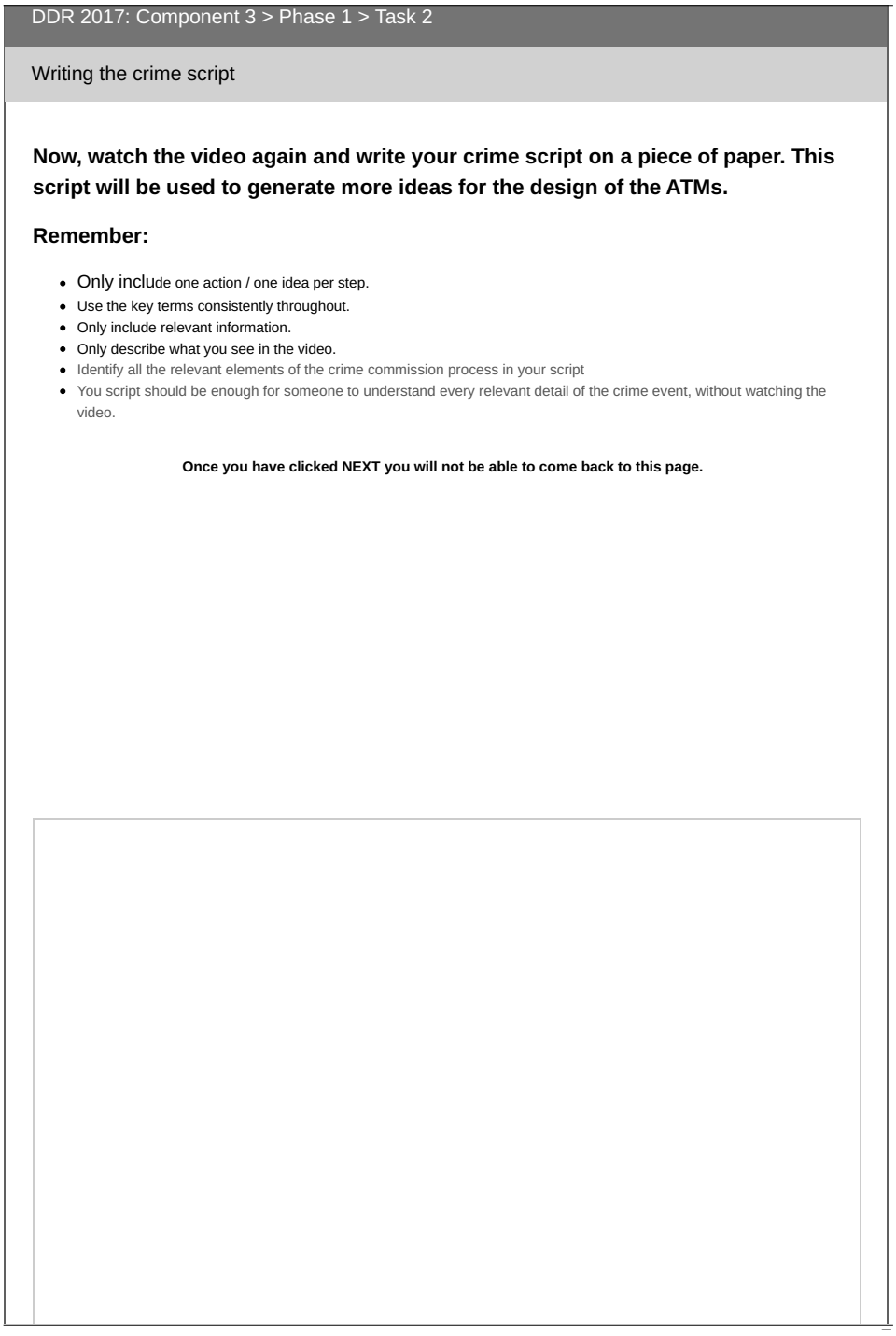


Figure D.7: An example of bank card theft experiment task (7/10)

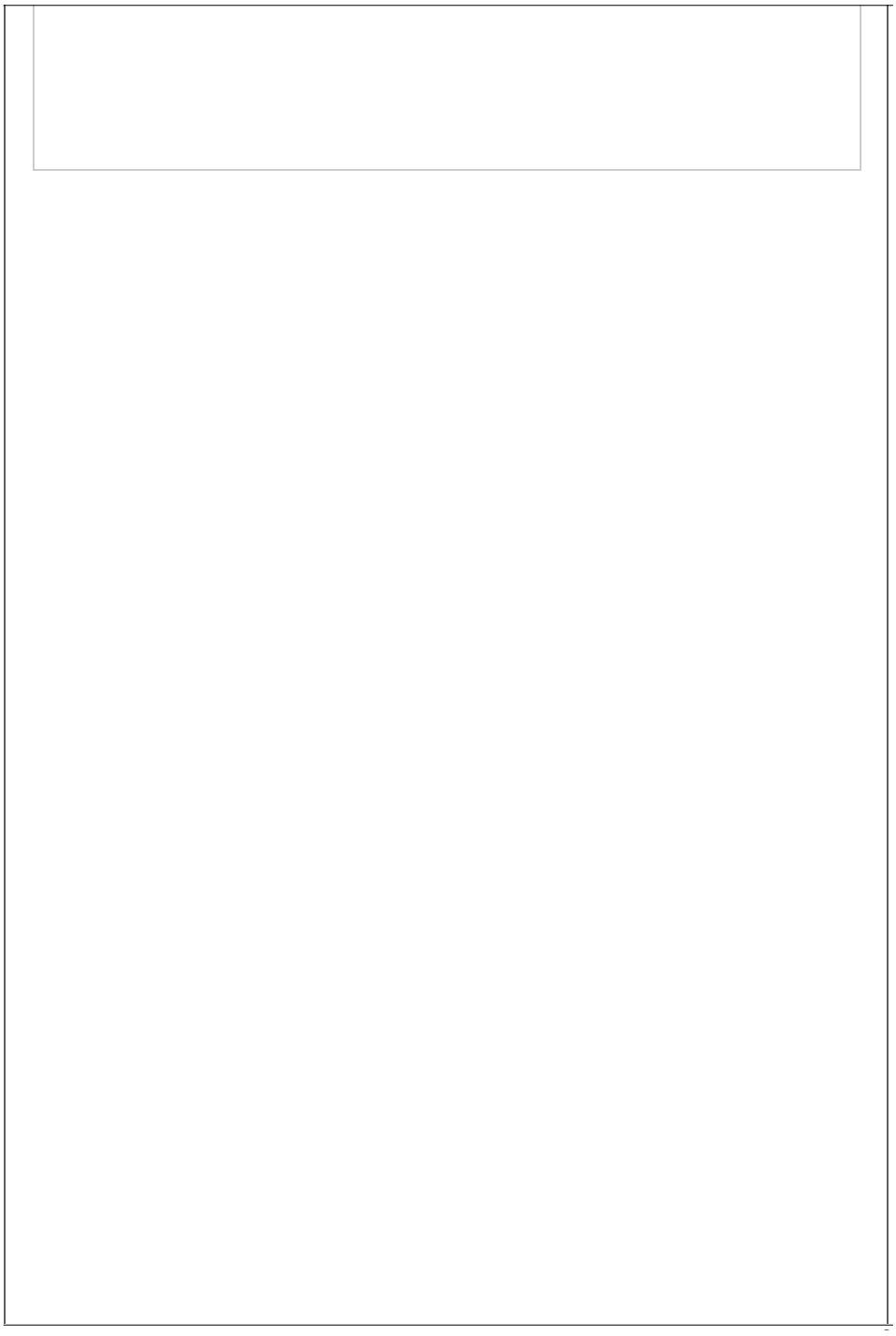


Figure D.8: An example of bank card theft experiment task (8/10)

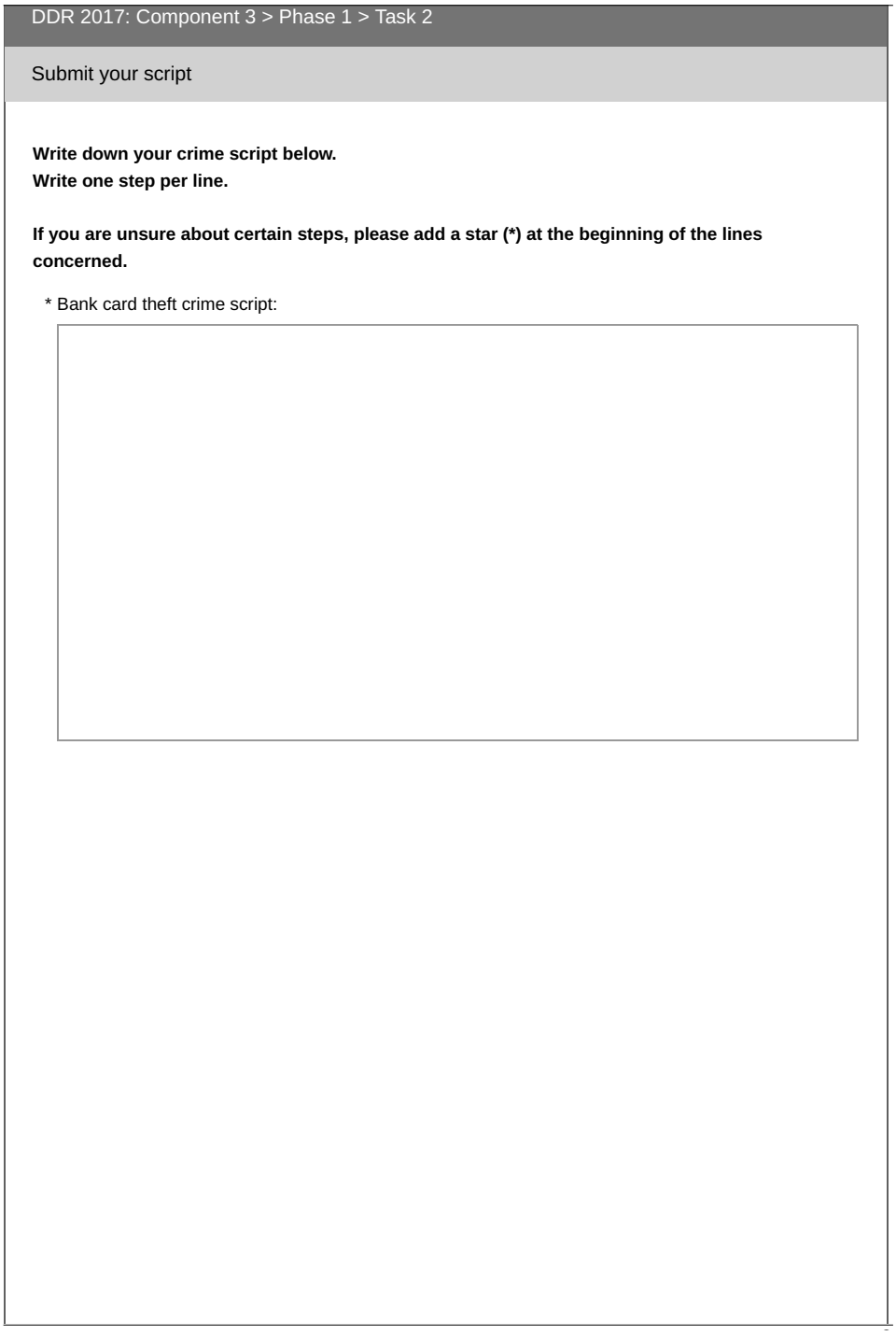


Figure D.9: An example of bank card theft experiment task (9/10)

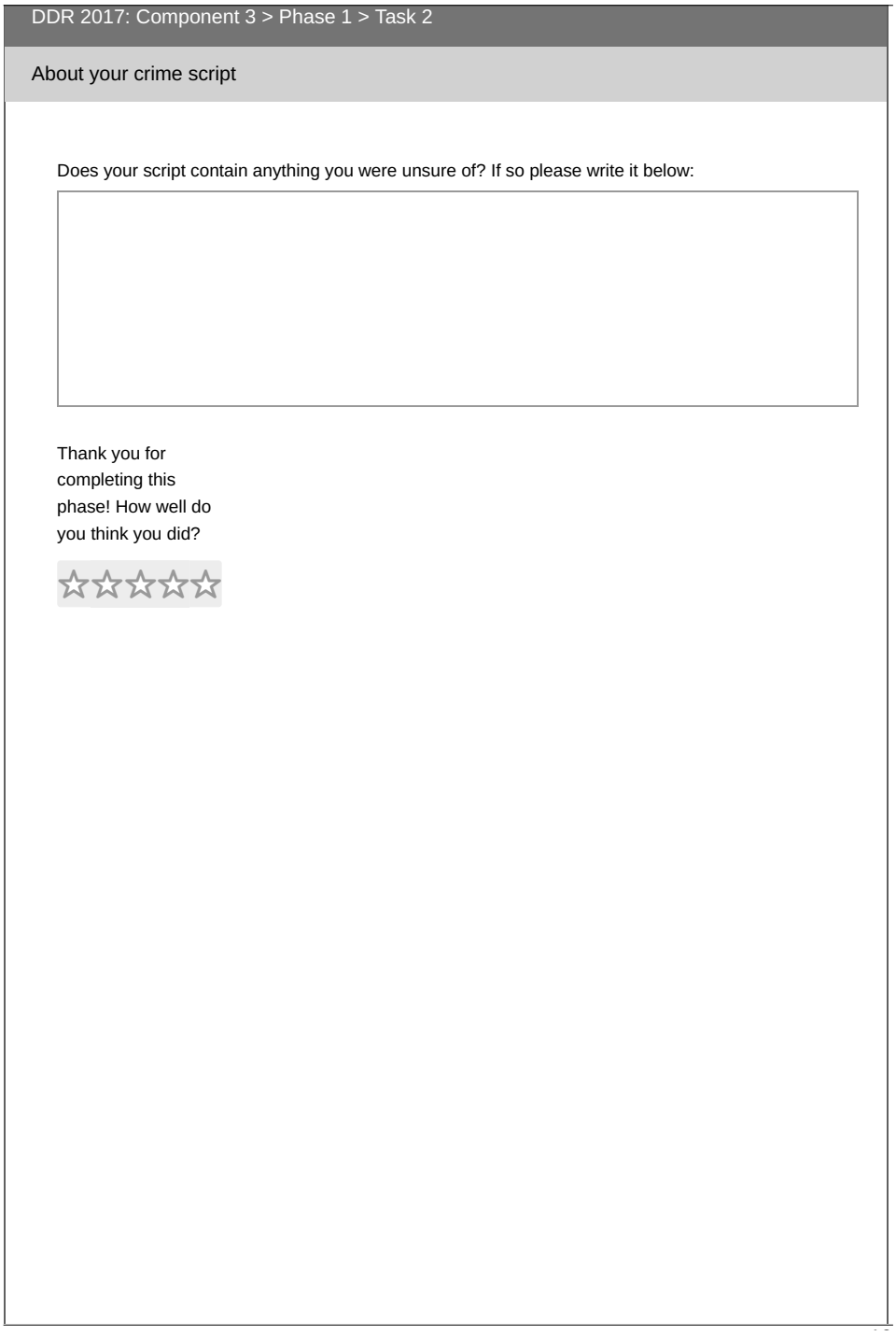


Figure D.10: An example of bank card theft experiment task (10/10)