

# Comparative Analysis of Crime Scripts: One CCTV Footage – Twenty-One Scripts

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**Abstract**—In recent years, there has been a growing interest in the modelling of crime commission processes, in particular crime scripting, in physical and cyber spaces. This article aims to demonstrate the limits of unstructured scripting approaches, and advocates the development of more systematic techniques. For this, we examined the differences and similarities between various scripts. Twenty-one participants were trained in crime scripting, and tasked to produce individual scripts based on the same video footage of a shop robbery. Content analysis was applied to the scripts, which involved classifying the different steps of the crime commission process and analyzing their distributions. A scoring system was then developed to assess the relative degree of completeness of each script, and linear regression computed using the number of activities included as the predictor variable. This research provides the first evidence of the limits of creating scripts using an intuitive approach, and the need for applying semi-structured goal-based methods.

**Keywords**—crime script, video, situational crime prevention, robbery, modus operandi

## I. INTRODUCTION

The need to better understand the ‘where’, ‘when’ and ‘how’ aspects of crime has been highlighted in many fields including criminology, operations research, video analytics, and cyber-security [1-4]. Cornish, one of the pioneers in this area, made a noticeable contribution known as the script-theoretic approach to crime reduction [5]. Building on the work of Shank and Abelson [6], he connected the concepts of crime modus operandi and psychological schema together, and outlined how the analysis of crime procedural models – now referred to as *crime scripts* – could “enhance situational crime prevention policies”. Specifically, his approach involves gaining a better understanding of offenders’ operational requirements and decision-making process to identify a fuller range of possible intervention points [5]. Over the year this approach has become applied to a variety of problems [7-12], including joyriding and pickpocketing, as represented in Tables I and II.

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TABLE I. THE JOYRIDING SCRIPT [5]

Stage	Action
Preparation	Offender (O.) gathers tools
Entry	O. enters parking lot
Pre-condition	O. loiters unobtrusively
Instrumental pre-condition	O. selects vehicles
Instrumental initiation	O. approaches vehicles
Instrumental actualization	O. breaks into vehicles
Doing	O. takes vehicles
Post-condition	O. reverses out of bay
Exit	O. leaves parking lot

TABLE II. PICKPOCKET SCRIPT BASED ON POYNER’S DESCRIPTION OF PICKPOCKETING [13]

Stage	Action
Preparation	Offender (O.) decides to pickpocket at a train station
Pre-activity	O. identifies appropriate target in a crowd
	O. nudges them from behind
Activity	O. apologises whilst pocketing the wallet
Post-activity	O. exits crowd
	O. removes cash and credit cards from wallet
	O. disposes of wallet
	O. pockets the cash
	O. takes credit cards to associate to exchange for cash
	O. spends cash

To those interested in reducing crime, the practical *value* of crime scripts is indeed dependent on their format and content. Recently, Borrión formalized 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 [14]. 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.

## II. METHOD

The quality of crime scripts is a concept built on the premise that some scripts are ‘better’ than others. Although this seems logical, we could not find any 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 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 [15]. For example, Balcetis and Dunning 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 preconscious processing of stimuli in the visual environment and thus “guide what the visual system presents to conscious awareness” [16].

To improve the way we reason about the generation, verification and validation of crime scripts, we carried out an exploratory study adopting a bottom-up method. We invited 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, we sought to achieve four objectives that would ultimately contribute to operationalize Borrión’s concept of quality assessment in this area [14]:

- 1) Validate a systematic method for characterizing 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 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, list recommendations.

### A. 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.

### B. Script generation

#### 1) Materials

##### a) Scripts used as illustration in the training phase

In the study, participants went through three phases: training, training verification, and scripting phases. In the former, we introduced the core principles of crime scripting and exposed them to the exemplar scripts represented in Tables I and II. These were extracted from Cornish’s seminal article [5] and online training materials used in a crime analysis short course [17]. In the absence of standardized instructions we 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.

##### b) Data used in the test phase

The participants generated their scripts based on a 33 second video footage representing an armed robbery at a local corner shop. There was no sound 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 12th December 2011 [18]. 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  $\times 2$  or  $\times 4$ ). As shown in Fig. 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.



Fig. 1. Image from the video footage (scripting phase). The offender (left) is pointing a rifle at the two employees behind the shop counter (right) [18].

## 2) Protocol

### a) Selection

The participants were invited to our university during three hours. Two activities were organized on that day that 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 study.

### b) Training Phase

The participants attended a 25 min. 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 analyze 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 continuing after it if knowledge of those events can inform crime reduction 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 I and II. Six participants asked questions about crime scripting; answers were provided to the entire group.

### c) Training validation phase

To ensure that every participant had met the intended learning objectives of the training before entering the test phase, a ten-minute 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.

### d) 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.

## 3) Script analysis

### a) Development of a classification system

To discuss the differences between the participants’ scripts, some comparison operators must be used. In our case, the lack of a shared ontology meant that two scripts could provide similar information about a given activity but describe it in different ways. To address this challenge, a classification system was developed based on the work of Berelson [19], Holsti [20], Smith [21], and Berg et al. [22]. The resulting six-stage method was close to that proposed by Burnard [23] for analyzing the transcripts of interviews with nurses:

(1) Listing all the steps of the scripts—Script content classification begins by analyzing the information in the first script, dividing it into distinct activities, and creating classes for those. The next step involves determining whether all the content of the second script can be classified using the created classes. If not, new classes are added to the list. After that, the third script is processed and so on.

Three rules were applied: (i) a script step describing multiple concepts can be decomposed and mapped onto more than one class; (ii) the order of the classes follows the order in which they appeared 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’).

(2) Splitting the classes—the list of classes is then reviewed and decisions to split some of them taken here. Splitting would typically occur when a class (i) contains multiple actors, (ii)

involves multiple locations or (iii) describes multiple actions that are deemed sufficiently important to be highlighted.

(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 Stage 3, this is verified to prevent class repetition and to minimize possible overlaps between classes. Following the method in [23], two classes are considered to overlap if they refer to the same activity, or if the information in one class is also in the other. In the latter case, the more detailed class is retained and the more general one is reviewed to determine whether (i) it is completely redundant or too general and should be deleted, or (ii) it can be divided into more detailed classes, in which case we return to Stage 2.

(4) Filtering out classes—Following the method detailed by Morse and Field [24], the classes in the list are then all individually reviewed to determine whether they are sufficiently unambiguous and detailed, and relate to the crime commission process. Any class that does not meet all these conditions is reconsidered and either modified or deleted.

(5) Re-ordering the classes—All the listed classes are then reviewed and re-ordered based on the chronological dependencies between them. Comparison is performed with preceding classes, starting from the last one; similarly to the bubble sort algorithm [25].

(6) Rephrasing classes—The classes are reworded to improve readability and consistency within the list.

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

#### 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) x 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’s kappa, as a measure of inter-rater reliability [26]. 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 we would expect:

- (i) every script step to correspond to at least one class in the classification system, and
- (ii) 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 [23] for interview data, considering the information omitted, split, or rephrased in the combining stage. However, unlike Burnard who relied on the participants to verify the scripts

themselves, we used a third party for this purpose. In the second part of the analysis, we refined the superscript using the results of the classification. This involved (1) Identifying areas of uncertainty and conflicts within and between scripts (2) Specifying the information to verify (3) Resolving identified issues using the video footage (4) Developing a ‘super-script’ and (5) Verifying the ‘super-script’.

#### Data Analysis

To characterize the differences and similarities between scripts, we 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:

$$\Theta = 1 - \sum w_j / J \quad (1)$$

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

The principle behind Eq. 1 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, we compared the same steps across several scripts to identify how they differed qualitatively.

### III. RESULTS

#### A. Classes

The resulting classification system comprises 40 classes: (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 look 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.

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 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 judgment 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.

### Scripts Analysis

Classes 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.

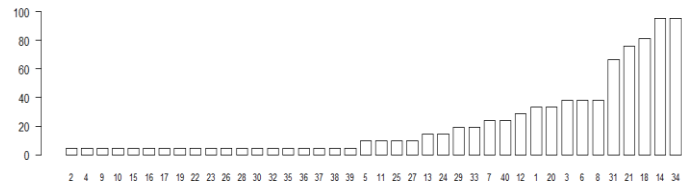


Fig. 2. Distribution of script steps across the forty activity classes (%)

As represented in Fig. 2, five (12.5%) of the 40 classes are found in more than 50% of the scripts. These are classes 14, 18, 21, 31 and 34 (in bold), with 14 and 34 mentioned in almost all scripts. Nineteen (47.5%) of the 40 classes are found in one script only.

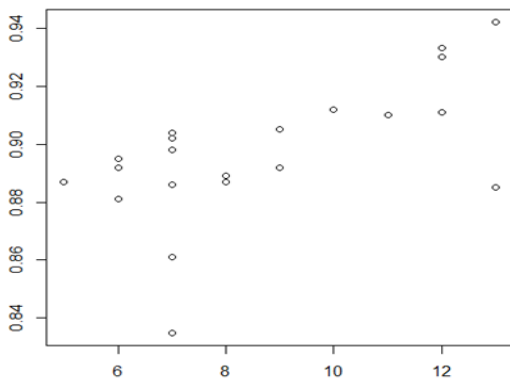


Fig. 3. Relative level of completeness (y) computed using equation (1) as a function of the number of steps (x) – (N=21)

A completeness score was computed for each script and represented in Fig. 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:  $\beta=0.0057$  ( $p < .05$ ). The overall model fit was relatively poor with  $R^2 = 0.35$ .

Components: Twenty-six components were identified in the pool of scripts: **(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. As represented in Fig. 4, the first eight (31%) of twenty-six components (in bold) are found in more than 50% of the scripts. Six (23%) components are found in one script only.

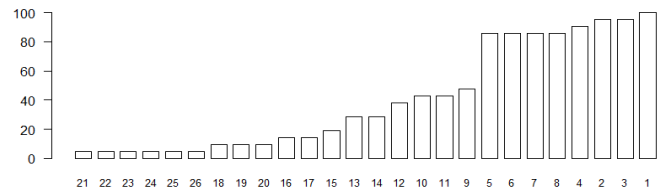


Fig. 4. Main components and proportion of scripts that report them (%)

## IV. DISCUSSION

### A. Findings

#### 1) Different scripters create different scripts

The results unambiguously show that when several individuals who received the same training about crime scripting watch the same video footage of a crime, 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 summarizing 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: (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 (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 article. 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 [2]. A different set of scripts could have been obtained if the other actors had been emphasized in the training phase, as suggested by Leclerc [27].
- 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 '(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 Scene Entry, Doing and Scene Exit elements of Cornish's universal script [5]. 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 be that participants may naturally be inclined to open and close their narratives. This idea has been developed by Ryan who wrote that "beginnings and ends are introduced in the taleworld by the storyrealm thus rendering consequential what is merely consecutive" [28].
- 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 [29, 30]. 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" [31].

### 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 judgment 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 Eq. 1). 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 #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 offender's 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 and Gill [32] in that "But even the most determinedly empirical descriptions of behavioural regularities will adopt the intentional stance [33] or theory of mind [34]."

### 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.

## B. *Limitations*

The quality and diversity of crime scripts is dependent upon a number of elements including the crime to be modelled, data source 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 generalizable to videos that have more or more complex scenes. Finally, those students were selected as participants to ensure they had some basic knowledge in the field of crime prevention but no prior experience of crime scripting. These design choices were the results of trade-off and bring certain limitations too. For example, some of the findings may not apply to individuals who would have gone through extensive training about crime scripts or situational crime prevention. If analysts with greater expertise in crime prevention and detection had served as participants, similar items may have been selected to construct the scripts. Likewise, the variation between scripts may be more limited if they are constructed based on other data sources, in particular narratives such as an offender's testimony.

## V. CONCLUSIONS

This exploratory study of video-based crime scripting practice has achieved all its objectives: A method has been presented that can be used to compare crime scripts produced by different analysts by statistically characterizing 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 an intuitive approach to crime scripting. We have also identified a number of plausible reasons why certain steps are more likely to be included in scripts than others, including the fact that many participants would have focused on what the offender did to achieve the primary objective (i.e., robbery) discarding considering other relevant actors or goals (e.g., not being caught, etc.). To conclude this article, we list five recommendations aimed at improving the quality of future scripts:

Firstly, we have shown that whilst the studied scripts cover a total of forty activities together, the scripts contain eight (20%) activities each, in average. The experiment should be repeated, ensuring that participants model the scenes that appear in the video only. Also more research should be conducted to exploit the diversity offered by multiple scripts, and resolve conflicts between them.

Secondly, whilst some level of interpretation might be useful to build more informative models, scripters should indicate whether the elements included in their scripts correspond to directly observed/reported events, inferences, or assumptions (including 'wild guesses').

Thirdly, we have listed plausible reasons that could explain why some steps are more frequently scripted than others. These

should be tested (experimentally) with more scripts in order to advance the guidance provided to crime scripters. More work should be conducted to understand the influence of individual biases and motivation on the selection of information.

Fourthly, researchers should create a more systematic and goal-based crime scripting technique that could outperform the current intuitive approach, and reduce the observed variance in quality. Providing a step-by-step method may provide analysts greater confidence in their results, and encourage them to publish their scripts.

Finally, if crime scripts are intended to be used for crime reduction, crime scripters should be trained to better identify the relevant information, including the elements that can help (i) specify effective control measures with limited negative consequences, and (ii) assess how suitable they would be if they were to be implemented.

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## REFERENCES

- [1] R. V. Clarke, "Situational Crime Prevention: Successful Case Studies. New York: Harrow and Heston," ISBN 0-911577-39-41997.
- [2] S. Kaplan, Y. Y. Haimes, and B. J. Garrick, "Fitting hierarchical holographic modeling into the theory of scenario structuring and a resulting refinement to the quantitative definition of risk," *Risk Analysis*, vol. 21, pp. 807-807, 2001.
- [3] S. E. Otu, "Patterns and Modus Operandi of Crime and Disorderly Conduct on the Public Transport System in Abakaliki, Nigeria: A Descriptive Analysis," in *Cybercrime, Organized Crime, and Societal Responses*, ed: Springer, 2017, pp. 341-365.
- [4] R. Willison, "Applying Situational Crime Prevention to the Information Systems Security Context (From Perspectives on Identity Theft, P 151-167, 2008, Megan M. McNally and Graeme R. Newman, eds.--See NCJ-223725)," 2008.
- [5] D. B. Cornish, "The procedural analysis of offending and its relevance for situational prevention," *Crime prevention studies*, vol. 3, pp. 151--196, 1994.
- [6] R. C. Schank and R. P. Abelson, *Scripts, plans, goals, and understanding: An inquiry into human knowledge structures*: Psychology Press, 1977.
- [7] A. Hutchings and T. J. Holt, "A Crime Script Analysis of the Online Stolen Data Market," *British Journal of Criminology*, vol. 55, pp. 596--614, 2015.
- [8] H. Dehghanniri, E. Letier, and H. Borrión, "Improving security decision under uncertainty: A multidisciplinary approach," in *Cyber Situational Awareness, Data Analytics and Assessment (CyberSA), International Conference on*, 2015, pp. 1-7.
- [9] R. Willison, "Understanding the perpetration of employee computer crime in the organisational context," *Information and organization*, vol. 16, pp. 304--324, 2006.
- [10] T. Somer, B. Hallaq, and T. Watson, "Utilising journey mapping and crime scripting to combat cyber crime and cyber warfare attacks," *Journal of Information Warfare*, vol. 14, pp. 39-49, 2016.



- [11] H. Dehghanniri and H. Borrión, "Toward a More Structured Crime Scripting Method," in *Requirements Engineering Conference Workshops (REW), IEEE International*, 2016, pp. 94-97.
- [12] H. Haelterman, *Crime Script Analysis: Preventing Crimes Against Business*: Springer, 2016.
- [13] R. Clarke and J. E. Eck, *Become a problem-solving crime analyst*: Routledge, 2014.
- [14] H. Borrión, "Quality assurance in crime scripting," *Crime Science*, vol. 2, p. 6, 2013.
- [15] D. A. Schum, *The evidential foundations of probabilistic reasoning*: Northwestern University Press, 1994.
- [16] E. Balçetis and D. Dunning, "See what you want to see: motivational influences on visual perception," *Journal of personality and social psychology*, vol. 91, p. 612, 2006.
- [17] L. Tompson, "Crime script analysis."
- [18] M. P. Department. (2011, 2017/07/20). *7-Eleven Armed Robbery*.
- [19] B. Berelson, "Content analysis in communication research," 1952.
- [20] O. R. Holsti, "Content analysis," *The handbook of social psychology*, vol. 2, pp. 596-692, 1968.
- [21] H. W. Smith, *Strategies of social research: The methodological imagination*: Prentice-Hall Englewood Cliffs, NJ, 1975.
- [22] B. L. Berg and H. Lune, *Qualitative research methods for the social sciences* vol. 5: Pearson Boston, MA, 2004.
- [23] P. Burnard, "A method of analysing interview transcripts in qualitative research," *Nurse education today*, vol. 11, pp. 461-466, 1991.
- [24] J. M. Morse and P.-A. Field, *Nursing research: The application of qualitative approaches*: Nelson Thornes, 1995.
- [25] R. E. Neapolitan and K. Naimipour, *Foundations of algorithms*: Jones & Bartlett Learning, 2011.
- [26] J. Cohen, "Weighted kappa: Nominal scale agreement provision for scaled disagreement or partial credit," *Psychological bulletin*, vol. 70, p. 213, 1968.
- [27] B. Leclerc, "New developments in script analysis for situational crime prevention," *Cognition and Crime: Offender Decision Making and Script Analyses*, p. 221, 2013.
- [28] M.-L. Ryan, *Narrative across media: The languages of storytelling*: U of Nebraska Press, 2004.
- [29] M. Toolan, *Narrative: A critical linguistic introduction*: Routledge, 2012.
- [30] D. Bordwell, K. Thompson, and J. Smith, *Film art: An introduction* vol. 7: McGraw-Hill New York, 1997.
- [31] B. Jung, T. Kwak, J. Song, and Y. Lee, "Narrative abstraction model for story-oriented video," in *Proceedings of the 12th annual ACM international conference on Multimedia*, 2004, pp. 828-835.
- [32] P. Eklblom and M. Gill, "Rewriting the Script: Cross-Disciplinary Exploration and Conceptual Consolidation of the Procedural Analysis of Crime," *European Journal on Criminal Policy and Research*, pp. 1--21, 2015.
- [33] D. Dennett, "The Intentional Stance (Cambridge, MA and London," ed: MIT Press, 1987.
- [34] A. I. Goldman, "Theory of mind," *The Oxford handbook of philosophy of cognitive science*, pp. 402-424, 2012.