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Child sexual abuse material networks on the darkweb: a multi-method approach

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A network diagram with nodes and connecting lines, overlaid on a dark gray background. Some nodes are represented by human silhouettes, while others are question marks. A large, stylized circular graphic is visible in the top right corner.

CHAPTER 4

PROFILING DARKWEB CSAM FORUM MEMBERS USING LONGITUDINAL POSTING HISTORY DATA

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Abstract

Darkweb fora dedicated to the illegal exchange of child sexual exploitation material (CSEM) continue to thrive. Profiling forum members based on their communication patterns will increase our insights in the dynamics of online CSEM and may aid law enforcement to identify those members that are most influential and pose the highest risk. The current study uses data from a large English language Darkweb CSEM forum that was active between 2010 and 2014, containing over 400,000 posts. Posts were time stamped, categorized based on subforum topic, and linked to individual forum members by nickname. Group-Based Trajectory Modeling (GBTM) was subsequently applied to derive forum member profiles based on members' posting history. Analyses show that over the course of the observation period overall activity levels – in terms of total number of posting members and the average number of posts per month per member – fluctuate substantially, and that multiple developmental pathways – in terms of monthly patterns in the frequency of posts by individual members – can be distinguished. Theoretical and practical ramifications of these findings are discussed.

4.1 Introduction

Despite the worldwide increase in law enforcement attention and evident public aversion to online child sexual exploitation material (CSEM), the illegal exchange of CSEM continues to thrive. An important explanation for this is the growing potential and speed of the internet. Platforms have emerged offering users high levels of anonymity, built-in countermeasures to hide illegal activity and reduce the risk of detection, 'on-demand' viewing, and unprecedented networking opportunities with like-minded others (Finklea, 2017; Steel et al., 2020). CSEM fora are now primarily located on the Darkweb, an encrypted part of the internet only accessible through specialized software such as the TOR webbrowser (DeMarco et al., 2018). Access to the Darkweb, and hence to Darkweb CSEM fora, is no longer limited to the technical savvy, but broadly utilized by offenders with varying technical dexterity (Goodman, 2015). While approximately 2% of TOR hidden services websites are CSEM related, estimates are that roughly 80% of TOR hidden service queries and traffic can be linked to CSEM (Owen & Savage, 2015). Academic research on Darkweb CSEM fora and their members is lim-

ited however, because, due to its content, merely accessing a Darkweb CSEM forum is illegal and would make researchers liable to prosecution.

Originating from researcher-practitioner collaboration, the current study utilizes a unique dataset pertaining to a large Darkweb CSEM forum to describe its evolution, and to profile forum members based on their online communications. More specifically, the current study aims to answer two related research questions:

1. How can the evolution of a large and general Darkweb CSEM forum be described, in terms of member numbers and the volume and nature of these members' forum activity over time?
2. Can distinct forum activity patterns – in terms of the frequency and topics of posts – be distinguished for forum members?

Answering these research questions provides insight into Darkweb CSEM forum members' online behavior and its development over time. Moreover, it shows which forum areas and content are most popular and which members are most prolific in their online communications.

4.1.1 Internet fora as online communities

On internet fora, members communicate by submitting posts and by reacting on postings of other forum members. Over time, this user-generated content develops into discussions, or 'threads', centered around certain topics. Internet fora vary greatly in their characteristics, such as its number of members, the breadth of its focus, and the duration of existence. Moreover, over time internet fora may evolve in aspects such as density, generalization, and posting intensity (Morzy, 2013). For example, whereas some fora continue to be characterized by a high 'on-topic' posting intensity, other fora morph into broad and general discussion platforms. Likewise, some fora begin small, and evolve into slightly bigger, yet still dense communities of concurring individuals, whereas other fora grow exponentially and attract many users who might not always be very active, but who use the forum primarily as a location to surf around and gain knowledge. Apart from their informative and practical usefulness, the social aspect of fora is often regarded as essential (Jin et al., 2010; Miller, 2016). As members often identify with the topic of the forum they engage in, these fora form the basis of what has been referred to as internet (micro)communities (Morzy, 2013; Özyer et al., 2013).

Research suggests that, in general, a small minority of forum members is responsible for the majority of forum activity. In fact, 'lurking' appears to be normal internet behavior, as on average lurkers are found to constitute 90% of all forum members

(Gong et al., 2015; Mousavi et al., 2017; Tagarelli & Interdonato, 2013). This may especially apply to fora dedicated to an illegal or otherwise unconventional topic (e.g. Dupont et al., 2016; Kleinberg et al., 2020). Nevertheless, lurkers are often found to be attached to the content of the forum and may derive their identity from it. This may lead them to take on a more active and engaged role at a later stage (Gong et al., 2015; Mousavi et al., 2017).

When it comes to Darkweb fora facilitating illegal behavior, knowledge on the development of such fora as a whole, as well as the behavioral trajectories of their individual members, is of great theoretical and practical value, and can contribute to allocating law enforcement resources to those fora and those members that pose the greatest risk.

4.1.2 Darkweb CSEM offender communities

Individuals who, in normal life, feel stigmatized for their norm divergent interests, or who wish to communicate about illegal topics are found to rely more heavily on the internet than individuals who wish to speak about more accepted and mundane topics of interest (Goodman, 2015). Given its high anonymity, this likely applies even more strongly to the Darkweb. On many Darkweb fora, illegal goods such as weapons and drugs are offered and sold, and cybercriminals, such as malicious hackers and phishers, gather to exchange their expert knowledge (Décary-Héту & Dupont, 2013; Dupont et al., 2017). First and foremost, these fora are criminal marketplaces: locations where illegal goods and services can be obtained (either in exchange for money or for other illegal goods and services in return) (Holt, 2012; Tzanetakis et al., 2016). Moreover, Darkweb fora allow for extensive communication on deviant topics, without being counterbalanced by the mainstream discourse (Holt et al., 2010). As such, in the Darkweb communities that emerge from these fora, crime and deviance can quickly become normalized (Van Hout & Bingham, 2013).

Unsurprisingly, CSEM communities have increasingly relocated to the Darkweb. As with other fora, Darkweb CSEM fora develop by the means of user-generated content and thus rely on users posting comments and content. The virtually anonymous nature of the Darkweb allows CSEM forum users to be forthcoming about their sexual interests and desires and makes them willing to share illegal material – and by doing so become active in building the forum’s content – with little risk of societal disapproval and stigma, and a likelihood of arrest and prosecution that is equally perceived negligible. Typically, CSEM fora enable users to submit series of posts, resulting in threads, that are placed within the various forum sections that in turn relate to topics of sexual interest (e.g. boys, girls), technical issues and forum management. Like other cybercriminal Darkweb fora, Darkweb CSEM fora function primarily as crimi-

nal marketplaces, where illegal goods – i.e. CSEM – are voluntarily exchanged between suppliers and demanders. Unlike other Darkweb marketplaces however, CSEM is often bartered rather than bought and sold, and commercial motives seem largely absent (Van der Bruggen & Blokland, 2021). CSEM fora also function to support an online community in which child abuse is normalized and even promoted, and in which forum members find respect, recognition and emotional bonding (Durkin & Bryant, 1999; Jenkins, 2001; O'Halloran & Quayle, 2010; Quinn & Forsyth, 2013; Steel et al., 2020; Van der Bruggen & Blokland, 2021).

As do other internet fora, individual CSEM fora may vary in focus, size, and duration of existence (Van der Bruggen & Blokland, 2021). Darkweb CSEM fora are typically structured by allocating members various roles, relating to their tasks, responsibilities and status within the forum community. This hierarchical order may include formal statuses like registered member, VIP member, moderator, or admin (Bartlett, 2014; Finklea, 2017; Goodman, 2015). The highest ranking members, the admins and moderators, are those members that are usually involved in establishing and managing the forum. Moreover, forum administrators and moderators typically organize the network's activities and advise and provide answers to questions from registered members (O'Connell, 2001). VIP members typically achieve their priority status because of their positive contribution to and engagement with the community. Finally, the bulk of members consist of the lower ranking members, who enter and exit the forum at any stage. These members may contribute to the forum by sharing and downloading CSEM, but they do not have a major role in the forum's development and maintenance. Lower ranking members may however, be motivated to rise within the forum's hierarchy in order to become respected, and to build a certain status. They can do this by portraying frequent forum and posting activity, by sharing increased amounts of (unique and new) child abuse material, by sharing stories and fantasies or by emotionally or technically supporting fellow forum members (O'Connell, 2001).

Against the background of prior research on internet fora in general (Morzy, 2013), and studies into the organization of CSEM fora in particular (O'Connell, 2001; Van der Bruggen & Blokland, 2021), the current study will first describe the evolution of the Darkweb CSEM forum that is the topic of this study. While the previous literature as yet offers little ground for deriving concrete hypotheses regarding the temporal development of such fora, describing this particular forum's evolution, in terms of member numbers and the volume and nature of these members' forum activity, is important to contextualize the posting behavior of individual members subsequently scrutinized.

4.1.3 Typologies of online CSEM offending

When trying to classify offenders according to typologies of online CSEM offending and hypothesize about patterns of forum behavior among the various types of individuals interested in CSEM, it is important to consider some of the psychology that drives individuals towards CSEM offending. Drawing on the more general theory of problematic internet use (Davis, 2001), Quayle and Taylor (2003) describe engagement with the internet by people with a sexual interest in children as a two-pronged, dynamic process in which individuals move through different stages of involvement. First, repeated exposure to online CSEM by itself is assumed to have a disinhibiting effect, fueling escalating patterns of CSEM consumption, both in frequency and severity. Second, the model recognizes the social aspect of online CSEM offending, which starts with the individual's realization that others are also engaging in the same behavior – thus providing grounds for justification of that behavior – and ends with them taking an active part in the online CSEM community. In this community, cognitive distortions regarding sexually engaging with minors and justifications for viewing and trading CSEM go unchallenged, perpetuating and further escalating individuals' offending behavior (Davis, 2001; Quayle & Taylor, 2003).

Although not yet as well developed and empirically researched as behavioral and etiological typologies of child sexual abuse offenders in general (DeMarco et al., 2018), various authors have aimed to further classify online CSEM offenders. These typologies may focus on offenders who use online communications to meet and groom minors online (DeHart et al., 2017; Tener et al., 2015; Webster et al., 2012), offender motivations for online CSEM offending (Elliott & Beech, 2009), offender behaviors related to online CSEM offending (Krone, 2004), or on a combination of the latter (Lanning, 2001). Lanning's (2001) typology of sex offenders using computers to access CSEM and sexually exploit children with its specific focus on both offender behavior and -motivation is arguably the most thorough and the most applicable to the purpose of the current study.

Lanning (2001) suggests a motivational continuum ranging from a nonsexual- to a deviant sexual motivation to underly online CSEM offending. Situational offenders, who are at one end of this continuum and search for child abuse material out of curiosity or impulsivity and who behave more opportunistic, are distinguished from preferential sex offenders, who search for child abuse material deliberately and repeatedly out of a certain sexual preference. According to Lanning (2001), both situational and preferential offenders consist of three subtypes. Among the situational offenders, 'Normal adolescents/adults' are characterized by impulsivity and curiosity, searching for online pornography and accessing wide ranges of (legal and illegal) sexual material. This subtype parallels Krone's (2004) 'Browser' type, who accidentally hits on

CSEM websites or material by browsing or responding to spam, and then knowingly saves the content. Second, ‘Morally indiscriminate offenders’ are sex offenders with a history of varied violent offenses and are primarily power/anger motivated. Finally, ‘Profiteers’ consider the crime of online CSEM with its low risk of identification as a lucrative way of making profit. Elliott and Beech (2009) alternatively label this group ‘Commercial exploitation offenders’.

Among preferential offenders, Lanning (2001) firstly distinguishes ‘Pedophiles’, who have a definite sexual preference for children. A second group of preferential offenders, ‘Diverse offenders’, has various deviant sexual interests, not specifically aimed at children. Finally, ‘Latent offenders’ potentially have illegal sexual preferences, but only start to act out when inhibitions are weakened and preferences are validated through online engagement and communication, mirroring the social part of the Quayle and Taylor (2003) model. These different types of preferential offenders parallel the ‘Secure collector’ subtype within Krone’s (2004) typology, who tends to be security minded and actively seeks material through secure networks.

The three-left hand columns of Table 4.1 summarize and describe the subtypes within Lanning’s (2001) typology.

Table 4.1 Typology of online CSEM offenders (Lanning, 2001) and their hypothesized forum behavior

Motivation	Type	Explanation	Hypothesized first forum activity	Hypothesized posting frequency	Hypothesized posting duration	Hypothesized posting focus
Situational	‘Normal’ adolescent/adult	Searching for online pornography out of impulsiveness/curiosity, leading to access to illegal pornography and sexual opportunities	Later stage (when the forum is most popular and accessible)	Relatively infrequent	Relatively short	When communicating at all: superficial and short, no focus on community building
	Morally indiscriminate offender	Power-anger motivated, potential history of violent offenses	Could both be at an early or later stage	Intermediate	Intermediate	Mainly on sexual topics, no focus on community building
	Profiteer	Financially motivated	n/a	n/a	n/a	n/a

Motivation	Type	Explanation	Hypothesized first forum activity	Hypothesized posting frequency	Hypothesized posting duration	Hypothesized posting focus
Preferential	Pedophile	Definite preference for children	Early stage (before the bulk of members become active)	Frequent	Longer	Community building
	Diverse offender	Wide variety of paraphilic/deviant sexual interests, no specific sexual preference for children	Could both be at an early or later stage	Intermediate	Intermediate	On a variation of sexual topics, no focus on community building
	Latent offender	Illegal and previously latent sexual preferences are validated online	Later stage	Increasing posting behavior	Longer	Increasing focus on community building

4.1.4 Different dimensions of forum members' online activity

In analyzing CSEM forum members' online behavior, we build on the criminal career paradigm (Piquero et al., 2003), an analytic approach that breaks down the longitudinal sequence of individual criminal behavior into several distinct dimensions, like onset, frequency, duration and crime mix (Blumstein et al., 1988). Whereas the criminal career paradigm is increasingly being used to examine the criminal trajectories of those who engage in sexual offending (Blokland & Lussier, 2015; Blokland, 2018), up to this date this approach is only sparsely applied to online CSEM offending (Fortin & Proulx, 2019; Westlake & Bouchard, 2015). Westlake and Bouchard (2015) applied the criminal career paradigm at the macro level to identify CSEM websites with the highest survival rate. At a micro level, Fortin and Proulx (2019) examined the content of hard disks belonging to males arrested and convicted for collecting CSEM online, and distinguished four developmental patterns based on monthly changes in the nature of the depicted abuse and the age of the child victims: a degenerating spiral pattern (37.5% of the sampled collections) – collections showing an increase in the severity of the depicted abuse and a decrease in the children's age -, the sexualized adolescent pattern (20%) – showing an increase in both the severity of the abuse and the victim's age -, a boy/girl-love pattern (20%) – showing a decrease in severity and victim's age -, and a de-escalation pattern (22.5%) – showing a decrease in severity and children

of increasing age. These patterns are taken to reflect offenders' sexual interests and habituation, but could also reflect the availability (or rather the lack thereof) of certain types of content.

Similarly using a micro-level criminal career approach, individuals' Darkweb cSEM forum behavior can be broken down into several dimensions. These dimensions include onset – or the timing of the first post, frequency – the number of posts during a certain time period, duration – the time between the first and the last known posting, and nature or mix – the topics of these posts. Applying these dimensions to Darkweb forum members' posting behavior allows for a fine grained description of different online behavioral patterns and the divergence or convergence of these patterns over time. Distinguishing different dimensions in individuals' posting behavior also allows for formulating more detailed hypotheses about the online behavioral patterns of Lanning's (2001) subtypes of online cSEM offenders.

4.1.5 Hypotheses

1. *The posting careers of situationally motivated normal adolescents/adults will show a late onset, low frequency, and short duration.*

According to Lanning (2001), situationally motivated normal adolescents/adults are not determinedly looking for Darkweb cSEM fora. It can therefore be assumed that they are not part of the 'in-crowd' of the cSEM community, and will only become active on the forum at a later stage of its development, when the forum becomes more well-known to the broader group of Darkweb users. Because this type of offender is primarily driven by curiosity, and not by an entrenched or looming sexual interest in minors, it is expected that their posting will be infrequent and only span a short period of time.

2. *The posting careers of morally indiscriminate offenders will show an intermediate onset, frequency, and duration, and will be predominantly sexual rather than social in nature.*

Depending on the level of previous engagement with (Darkweb) cSEM communities, the morally indiscriminate offender could first become active at earlier as well as later stages of the forum's existence. Because of them being power/anger motivated, we expect their posts to be sexual rather than social and community-focused in nature. Moreover, because of their violent inclination, morally indiscriminate offenders may also show a preference for hardcore, rather than softcore material. Hardcore cSEM is typically violent and sexually diverse nature, rather than focused on 'the love for children'.

Given that previous qualitative studies of the forum analyzed here give no reason to presume that on this particular forum CSEM is exchanged for commercial purposes (Van der Bruggen & Blokland, 2021), Lanning's (2001) profiteer type offender is therefore rendered not applicable to the forum under scrutiny.

3. *The posting careers of preferentially motivated pedophiles will show an early onset, high frequency and long duration, and will be both sexual and social in nature.*

Preferentially motivated pedophiles are hypothesized to be most dedicated to the Darkweb CSEM community. Hence, they are the group most likely to have a role in the forum's organization and be active in its earliest stages. Moreover, they are likely to portray frequent posting behavior for longer periods of time, and, besides having a sexual interest in minors, show a serious interest in and dedication to the social aspect of the CSEM community. Finally, they are likely to specifically search for material that matches their sexual preference.

4. *The posting careers of diverse offenders will show an intermediate onset, frequency and duration, and will be predominantly sexual rather than social in nature.*

Due to their wide variety of deviant sexual interest, diverse offenders are hypothesized to be dedicated to the specific CSEM forum and to the Darkweb CSEM community as a whole to a lesser degree than the pedophile subgroup. While their diverse sexual interests may translate into frequent posting behavior over extended periods of time, it will not be as focused on community building than that of the pedophile subgroup. Similar to the morally indiscriminate offender, the diverse offender is likely to collect and share material of any sexual content.

5. *The posting careers of latent offenders will show a late onset, increasing frequency and long duration, and will for a large part be social in nature.*

Finally, the latent offender is expected to portray a late onset, escalating offending pattern. New to the CSEM community, this offender group is likely to first become active at a later stage of the forum's development. Encouraged and validated by the forum environment, over time their latent sexual preferences become more entrenched, and their posting behavior is expected to increase accordingly. Latent offenders can become active CSEM community members, and over time the nature of their posts is therefore expected to reflect both the sexual and social aspects of their online behavior.

The right section of Table 4.1 summarizes hypotheses relating to how the various online CSEM offender subtypes translate to the different dimensions of their forum behavior.

4.2 Methods

4.2.1 Data collection

To describe the evolution of a Darkweb CSEM forum and explore possible patterns in forum members' posting behavior, data from an English language Darkweb CSEM forum were collected. The forum was selected after consulting experts from a dedicated law enforcement child exploitation team and based on its general nature and large size. Forum information originated from international law enforcement investigations and was available within the premises of the federal police unit. Data collection took place in conjunction with a senior software engineer working for the Dutch law enforcement's cybercrime division, using a proprietary tool for forensic data analysis. This tool was a police in-house developed software tool to automatically prepare, congregate, structure, and process large amounts of digital data in order to enable further analysis. The comprehensiveness of the data was checked by creating overviews and visualizations of all forum threads, topics, and titles.

4.2.2 Forum posts and categorization

The above process resulted in a dataset of all posts submitted to the selected forum for the complete period that the forum was known to be online, which was December 2010 to December 2014, when the forum was taken down by law enforcement agencies. The posts submitted to the forum were time stamped and linked to individual forum members by their online nickname. Next, a person-month dataset was constructed that for each forum member for each month of the observation period, counted the number of posts under a certain topic category. The number and topics of posts were then used to analyze both the development of the forum as a whole, as well as the behavioral development of its individual members. Table 4.2 summarizes the characteristics of the forum.

Table 4.2 Characteristics of the forum

Forum characteristic	Forum characteristic outcome
Available data	December 2010 – December 2014
Observation period	49 months
# Threads	105,616
# Subfora	34
# Unique posts	420,222
# Unique posting members	14,838
Average # posts per month	8,576
Average # posts per active member	28.3

Using forum posts as the unit of analysis introduces some important caveats best mentioned upfront. First of all, the dataset contained posts from the publicly accessible part of the forum. There was no access to messages that were exchanged between individual members privately. As it may be expected that forum members share the most personal and sensitive information privately, not having access to these communications is a first limitation of the current study. Moreover, given the nature of the available data, we are only able to analyze the evolution of the forum and the behavioral patterns of its members based on the posting behavior of those forum members who are communicatively active on the forum. Hence, we do not have information on the number or online behavior of those only 'lurking' on the forum, but not participating in its online communications. Given prior estimates, the total number of unique visitors to the forum during the observation period is expected to be much larger than the total number of posting members (Gong et al., 2015; Mousavi et al., 2017; Tagarelli & Interdonato, 2013). However, the forum under scrutiny had an application process where new forum members had to make a formal application post before gaining access to the contents of the website. This post had to contain a certain amount of CSEM, meant for new forum members to show their willingness to participate in the community and for them to prove that they were not law enforcement. Furthermore, the forum enforced a policy requiring members to contribute to the forum at least once a month for them to maintain full access to the forum. Because of these procedures, it is expected that the share of lurkers is lower for this particular forum compared to other internet fora.

Forum posts were first categorized based on the thread they originated from. As the forum consisted of large numbers of threads ($N=105.616$), further categorization took place on the subforum level. The subforum is assigned by the forum itself, and consists of a forum webpage where content of a certain topic (for example hardcore, softcore, boys, girls) is gathered. As the current forum listed 34 subfora, a final manual categorization was conducted. This categorization was done based on the content of the thread- and subforum title. For example, a thread title such as 'Safe surfing on Tor using PGP' or a subforum title such as 'Tech Zone' was categorized under the category 'Information and technical safety'. When a thread title was applicable to more than one category, the subforum title was leading for deciding to which category the posts was assigned. For example, a thread title such as 'My first anal, 3y old boy' originating from a subforum called 'Hardcore' was categorized under the category 'Boys hardcore'. This final categorization yielded eight mutually exclusive categories: CSEM general, Girls Softcore, Girls Hardcore, Boys Softcore, Boys Hardcore, General discussion, Information and technical safety, and Restricted areas.

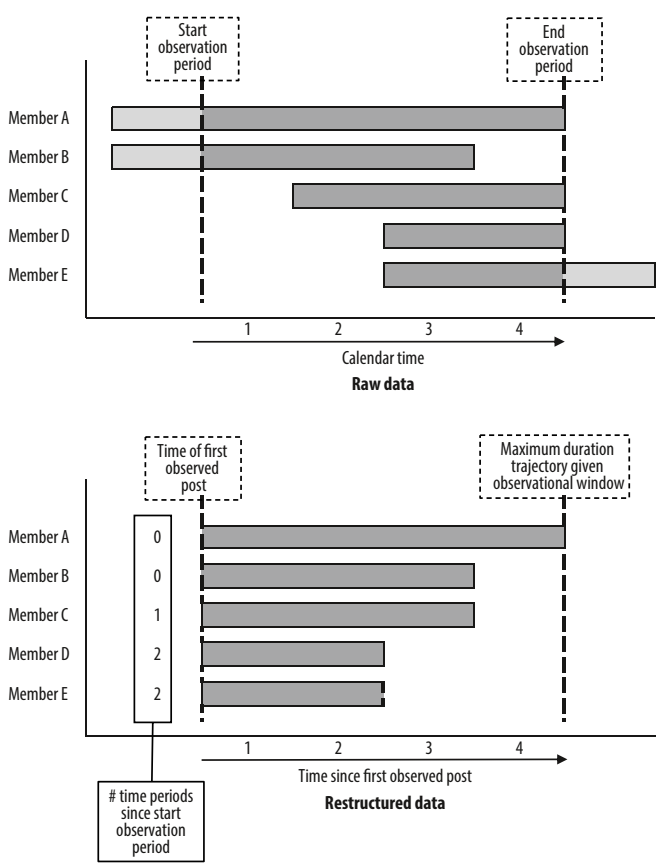
4.2.3 Forum member roles

Forum posts were linked to the nickname individual members were obliged to choose when registering as a member. On the forum under scrutiny, forum administrators assigned forum members with one of a number of statuses. Each status came with different privileges and levels of access to the forum. For the purpose of our analyses, we distinguish ‘Administrators’, the highest ranking category that included the Head administrator, Administrators and Co-administrators, and Global moderators; ‘VIPs’, privileged members including Producers, svip, vip, and other honorary members; ‘Registered members’; ‘Full members’; and ‘Inactive members’. The latter three categories were differentiated by the extent to which they were able to meet the forum’s posting requirements. Registered members are in the process of getting full access to the forum and are awaiting approval of their mandatory application post by the forum administrator. Once the content of this initial post is evaluated and their application is approved, the registered member is upgraded to ‘Full member’ and granted full access to the forum (excluding restricted areas only accessible for VIPs and Administrators). In the event full members subsequently were not able to meet the required level of monthly activity on the forum, they could be downgraded to ‘Inactive members’ and consequently lose full access to the forum.

4.2.4 Analytic strategy

The current study applied the method of Group-Based Trajectory Modeling (GBTM) using the Traj plug-in for Stata 13 (Jones & Nagin, 2013; Nagin, 2005). GBTM applies finite mixture modelling to cluster longitudinal data in a discrete number of trajectories that are allowed to vary both in level and in shape. Since their introduction in the mid-1990s, GBTMs have been used by criminologists and developmental psychologists to distinguish developmental patterns in various outcome behaviors including violence, delinquency and crime. Though different in topic and scope, what most of these studies have in common is that models are estimated on data covering some fixed time period that is demarcated by respondents’ calendar age. Hence, any developments observed in the trajectories distinguished can directly be linked to different time periods in the individual’s life span. In turn, this has fueled offender categorizations like ‘adolescence-limited’ or ‘adult-onset’. In the present study however, we have no information on forum members’ calendar age. Instead, for each posting forum member, the start of the posting trajectory is defined by the moment of the first post. Any developments in a member’s posting behavior are therefore to be interpreted against the number of months that that particular member is active on the forum under study. Figure 4.1 illustrates the implications of restructuring the data in this way.

Figure 4.1 Schematic representation of the effects of restructuring the longitudinal posting data for five hypothetical forum members



One important caveat of defining developmental trajectories this way is that for an unknown portion of members, the posting trajectory may be left-censored – i.e. these members may have posted their first post on the forum already prior to the start of the current study’s observational window (members A and B in Figure 4.1). Their first post observed may therefore not signal their actual introduction to the forum. While we have no way of knowing how long members may have been active on the forum prior to their first observed post, we can relate the timing of that first post to the start of the observational window. The longer the time period between the start of the study’s observation period and a particular member’s first post, the more confident we can be that this post represents the first activity of that member on the forum under scrutiny. Given the overall development of the forum under scrutiny however (see the Results section), left censoring does not seem very problematic for our analysis.

Data may also be right-censored (member E in Figure 4.1), when individual behavior continues after observation and data collection have stopped. In the present case however, the observation period ends with law enforcement taking down the forum, hence all members still active were forced to stop their posting on the forum. While for all posting forum members the end of their observed trajectory is therefore demarcated by the end of the observational window, the period between members' first observed post and the end of the observational window varies. When grouping forum members based on the patterning of their posting behavior, this may result in groups for whom the number of observations – that is, time periods over which data is available – varies.

GBTM probabilistically assigns members to each of the trajectory groups. For the current analysis members were assigned to the group with the highest posterior probability of assignment. This allowed for a formal comparison of posting behavior across trajectory groups using one-way ANOVA. As analysis evidenced unequal variances (variance ratio exceeding 1.5), and trajectory groups of unequal size, we employed the Brown-Forsythe and Welch ANOVA versions followed by Games-Howell post hoc tests. These analyses were conducted using SPSS 24.

4.3 Results

4.3.1 Descriptive analysis

Table 4.3 provides descriptives for the forum under scrutiny. In total, the forum consisted of 420,222 posts, posted by 14,838 unique members. The topic 'cSEM general' has the largest number of posts and the largest number of posting members. This is because this subforum included the 'Applications' subforum where all prospective members were obliged to post a first message in order to receive membership status. The topic 'Girls hardcore' is the second most popular topic both in terms of number of posts ($N=89,493$) as in the number of posting members ($N=4,874$). Both 'boy' categories are less popular, which might reflect a tendency for those with a sexual preference for boys to visit dedicated boy fora. Both hardcore categories (girls and boys) are more popular than soft core categories.

As expected, administrators make up only a very small proportion of the total number of individuals active on the forum, but are responsible for a disproportionately large part of the communications. The same applies – be it to a far lesser extent – to members with VIP status.

Table 4.3 Descriptives of the Darkweb CSEM forum, December 2010 to December 2014

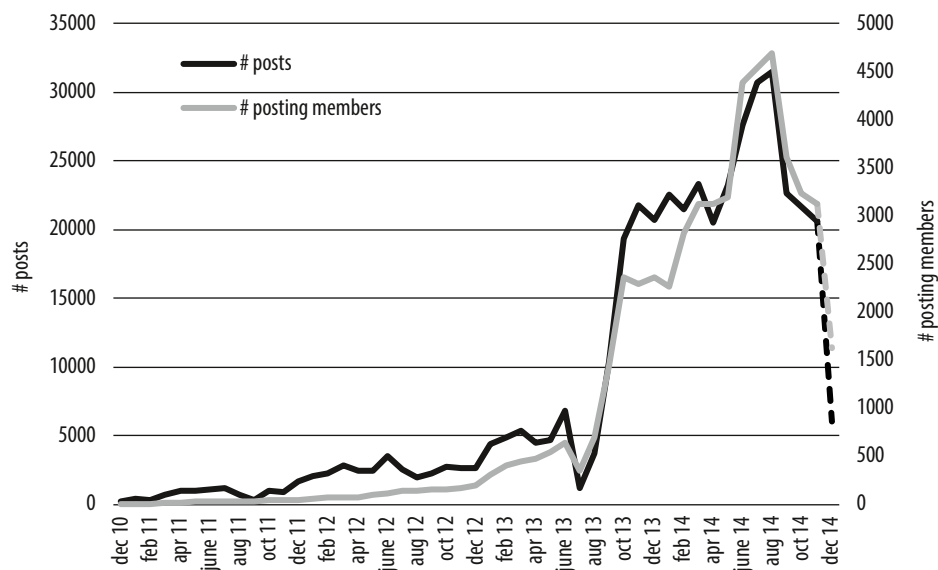
	# posts	% posts	# members	% members	# posts per member	this category includes
Total	420,222	100.0	14,838	100.0	28.3	
CSEM general	161,104	38.3	142,08	95.8	11.3	Applications, Webcams, Request Zone, Studios, Amateur
Girls hardcore	89,493	21.3	4,874	32.8	18.4	Girls hard
General discussion	47,304	11.3	2,338	15.8	20.2	General, Misc, Stories, Discussion Board
Boys hardcore	36,497	8.7	2,280	15.4	16.0	Boys hard
Girls softcore	28,964	6.9	2,751	18.5	10.5	Girls non-nude, Girls Jailbait, Girls soft
Restricted areas	25,207	6.0	891	6.0	28.3	VIP, Producer Lounge, Private Zone, SVIP, VIP zone, Boys VIP, Girls VIP
Boy softcore	20,488	4.9	1,351	9.1	15.2	Boys non-nude, Boys Jailbait, Boys soft
Information and technical safety	11,165	2.7	1,395	9.4	8.0	Rules and Tutorials, Tech Zone, Safety, Team Zone, When the chips are down, Forum world, Welcome, Tutorials, Translations
Administrators	64,743	15.4	22	0.1	2942.9	Head Administrator, Administrator, Co-Admins, Global moderator, Producers
VIPs	133,167	31.7	544	3.7	244.8	SVIP, Honorary member, VIP
Full member	141,954	33.8	4,480	30.2	31.7	Full member
Registered member	10,584	2.5	5,132	34.6	2.1	Registered member
Inactive member	50,262	12.0	4,565	30.8	11.0	Inactive member

Note The number of posting members per topic does not add up to the total number of members as members may post under multiple topics.
The number of members per formal status adds up to the total number of members as members are allocated only one formal status.

4.3.2 Forum evolution

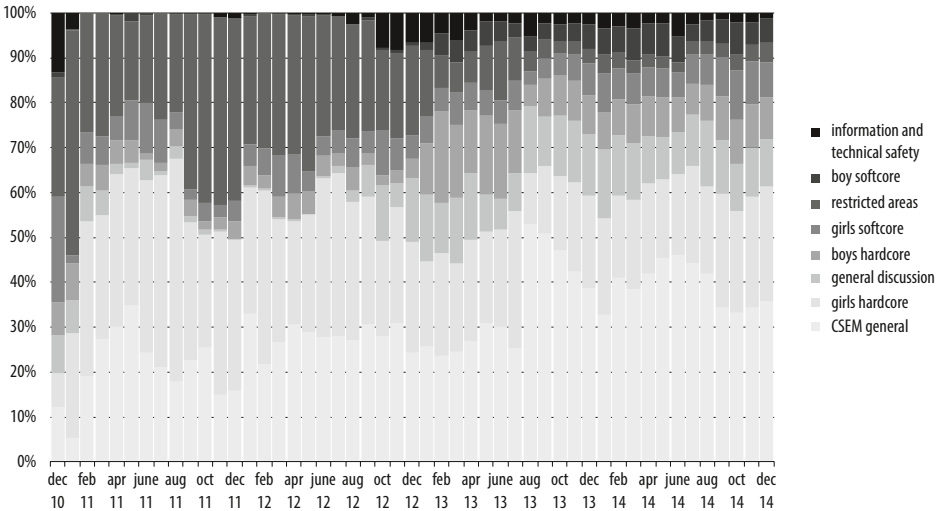
To answer our first research question, we add a temporal dimension to our descriptive analyses and describe the evolution of the forum, in terms of member numbers and the volume and nature of its communications. Figure 4.2 depicts both the total number of posts as well as the total number of unique members posting on the forum for each month of the observation period. Figure 4.2 shows the forum's evolution can be broken down in a 'start-up' period and a 'fully functional' period. During the first 32 months (December 2010 – July 2013) the number of posts is relatively low and increases to a maximum of 2,353 per month. The number of active members is also low, topping at a maximum of 638 during this period. As of September 2013 however, the number of posts increases steeply, from 10,415 post in September 2013 to a peak of 31,412 posts in August 2014. As is evident from Figure 4.2, this rise in forum activity is due to a simultaneous steep rise in the number of posting members which increases from 1,442 in September 2013 to a peak of 4,691 in August 2014. Put another way, between September 2013 and August 2014 over 700 new members enter the forum each month. The average number of posts per posting member decreases during this period, suggesting that the forum is attracting an increasingly broad array of individuals. This interpretation of forum evolution is supported by additional analysis showing that the share of administrators among posting members steadily decreases from one third early 2011 to less than 1% as of October 2013 – this despite the absolute number of posting administrators increasing from 3 during the first 3 months of observations to around 20 in the spring of 2014. With the number of forum members increasing, it is only logical that more administrators are needed to manage the forum. Subsequent analysis of the underlying case file showed that in August 2013 the forum went temporarily offline only to return with a new head administrator and new hosting platform. Under this new administrator the forum became an open forum (open to new registrations) and various new topic areas were added. The restricted areas remained available for members with a certain status, but the bulk of new forum members did not have access to these VIP areas.

Figure 4.2 Number of posts and number of unique posting members per month



The monthly percentual distribution of posts per topic is given in Figure 4.3. Posts in the ‘csem general’ category are prevalent across the entire observation period. In part, this can be explained by the continuous influx of new members posting their mandatory entrance application under this topic. Moreover, this category includes the ‘Request Zone’, which is where members can request certain material from other members. In terms of victim gender, the forum becomes slightly more balanced over time, the number of ‘girls hardcore’ posts giving way to posts under the ‘boys hardcore’ category, possibly reflecting growing variation in members’ sexual interests. The monthly distribution of posts across topic also illustrates the finding that during the first half of the observation period forum access is restricted to a small group of ‘in-crowd’ members, with much of the communication going on in the ‘restricted areas’ part of the forum. During the second half of the observation window, the number of posts in the ‘general discussion’ category increases, reflecting the growing social function of the forum. Educating new members on how to safely upload and exchange csem material also becomes more important, as is evidenced by the increase in posts under the ‘information and technical safety’ category.

Figure 4.3 Percentual distribution of the total number of monthly posts across topic category



4.3.3 Forum members’ communication patterns

In line with prior research on internet fora, we find that the distribution of posts is heavily skewed, with a minority of members being responsible for the lion share of all communication on the CSEM forum (Figure 4.4). 36% of forum members only contribute a single post to the forum, their posts representing 1.3% of all posts. Again, this likely reflects the forum’s policy to demand from potential members to make at least one obligatory post to the forum before gaining access to CSEM. If given the opportunity, forum members with a low number of posts might have chosen only to ‘lurk’. The 109 most active members (0.7% of all members), each contributing over 500 posts, on the other hand account for 40% of the forum’s public communications. Analyses in which we broke down the number of posts and posting members by topic reveal a similar skew in posting across topics.

Next, we examined the diversity of individual members’ posting behavior. Diversity was calculated using an adjusted version of the Simpson diversity index that ranges from 0, indicating that all posts are under a single topic, to 1, indicating an equal spread of posts across topics (Simpson, 1949). We calculated diversity for each forum member that posted at least two separate posts (64% of the total sample). Figure 4.5 shows the diversity of the totality of an individual member’s posting behavior by the total number of posts for that member. The size of the circles is relative to the number of members showing a certain total amount of posts and a given diversity. Figure 4.5 shows that diversity is higher among more active members. In fact, of those members posting between over a 100 posts, only 5.2% has a diversity below 0.5.

Figure 4.4 Distribution of posts (December 2010 to December 2014)

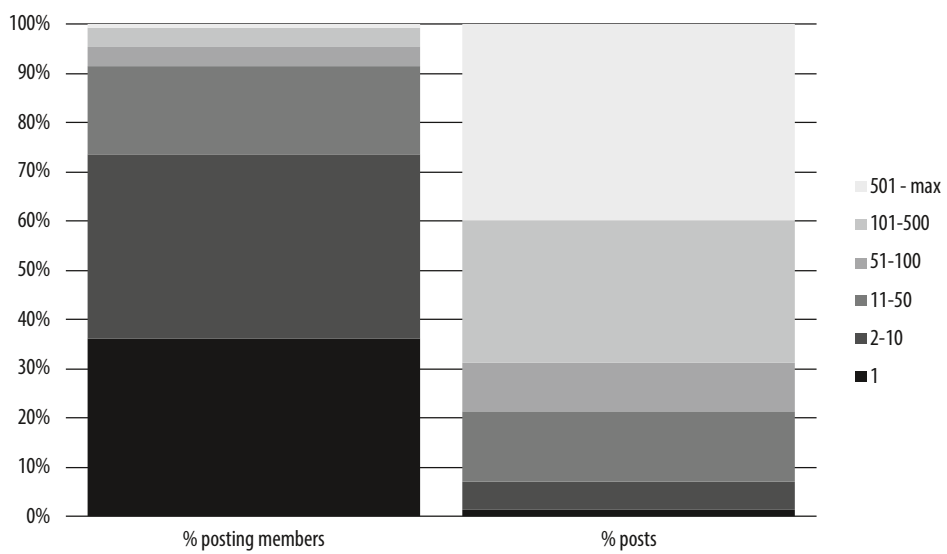
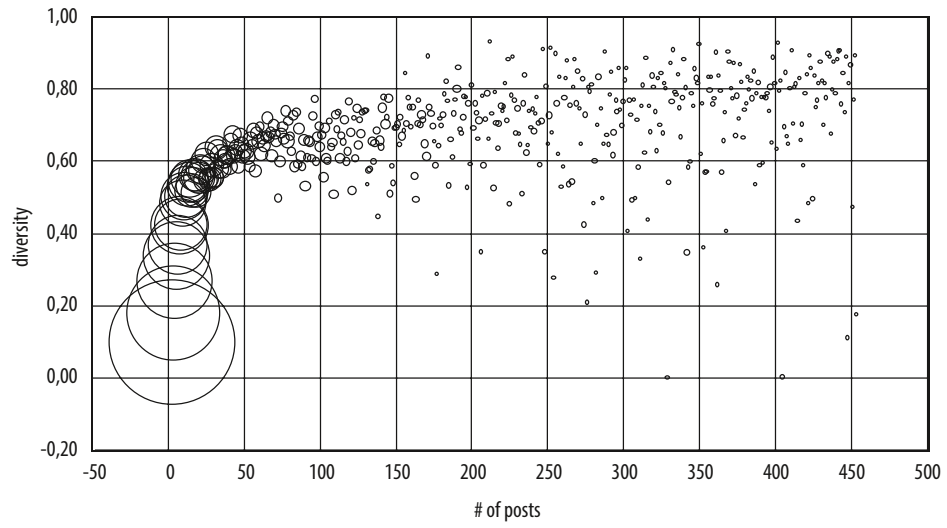


Figure 4.5 Diversity of the total posting volume by total number of posts



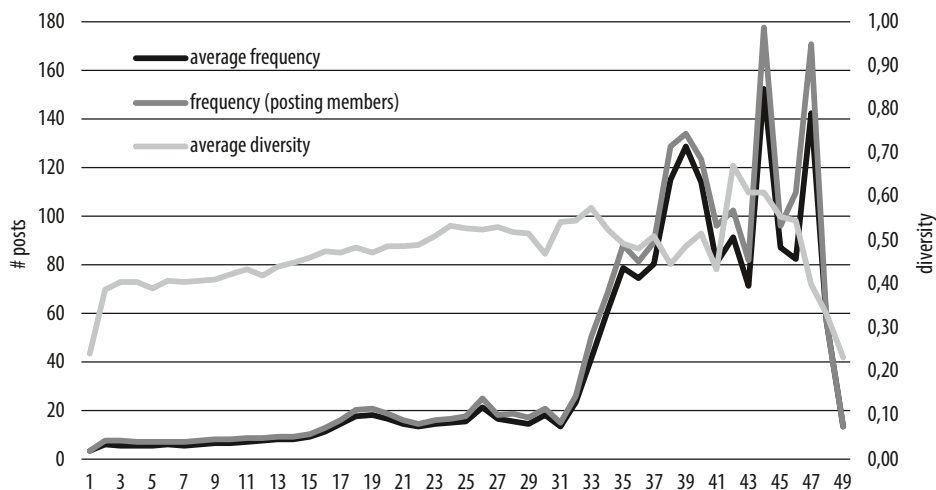
By structuring the data based on the month of first post (right-hand side of Figure 4.1), we can shift our attention from the evolution of the forum as a whole (i.e. calendar time on the x-axis) to the development of individual members' posting behavior as their posting 'career' on the forum progresses (i.e. month since first post on the x-axis). Figure 4.6 shows the average number of posts per member and the average num-

ber of posts per posting member for each month of members' posting career, as well as the average diversity of the posts across different topics. Unlike in Figure 4.5, where diversity was calculated across members' entire posting career, in this analysis, diversity was calculated on a monthly basis, only including months with at least two posts.

From the line depicting the average number of posts it can be concluded that posting frequency increases the longer members remain active on the forum. Figure 4.6 further shows that posting diversity is positively related to the length of the posting career: the average monthly diversity of posts shows an increasing trend across the number of months since the first post.

Figure 4.6 does show a sharp increase in the number of posts for those members whose posting career exceeds 31 months. Importantly, this increase is not simply the same as that shown in Figure 4.2, though both developments are related. Rather, the increase in Figure 4.6 results from selection. Like overall posting frequency, the distribution of posting career duration – that is, the number of months between a member's first and last post – is heavily skewed. The average posting career lasts for only 3.25 months, and the posts of 54.7% of members are concentrated within a single month. Therefore, with increasing length of the posting career, increasingly fewer members contribute to the average posting frequency depicted in Figure 4.6. Given the total length of the observation period (49 months), for every consequent month the averages in Figure 4.6 increasingly reflect the posting behavior of members who were already active during the 'start up' period of the forum and whose careers appear characterized by a high posting frequency. As such, Figure 4.6 underscores the need to distinguish between different CSEM forum member types based on their posting histories.

Figure 4.6 The average number of posts and the average diversity of posting by members' posting career duration



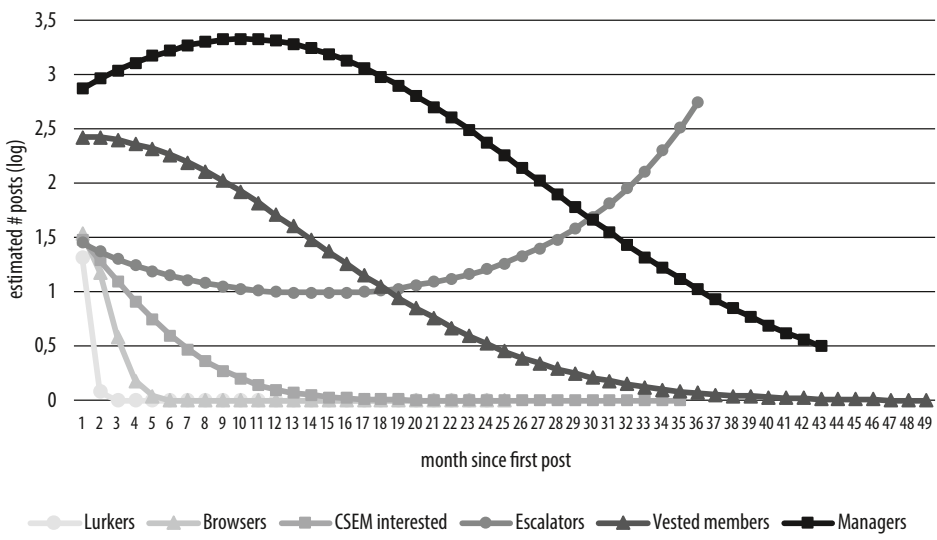
4.3.4 Distinguishing member types based on their posting trajectory

We used GBTM to distinguish distinct posting trajectories. Estimating the group based trajectory models, two issues became apparent. First, given both the large number of forum members and the large number of observations per member, estimating trajectory models on the total sample would take untenably long. Hence, to keep analysis time within limits, we drew a random 10% analysis sample ($N=1,502$) of all forum members to perform the GBTM. Standardized differences comparing this 10% sample to the remaining 90% of the original sample on relevant characteristics, like the average number of posts and the number of members actively posting (overall and across different topics), the average month of first and last post, and distribution of formal member statuses, revealed no significant differences between these subsamples (see Appendix Table A1). Therefore, we are confident that our analysis sample adequately reflects the forum's membership as a whole. Second, to deal with the large differences in the number of monthly posts per member, we log transformed the raw post counts, effectively reducing the skew in the data.

We estimated GBTM with up to seven groups. Model fit was assessed by the Bayesian information criteria (BIC), Akaike information criteria (AIC), and LL values, as well as additional criteria of model fit mentioned by Nagin (2005). Information with regard to model fit is provided in Table A2 in the Appendix. We found that BIC and AIC values continued to increase with each new group added – a feature commonly observed in large samples

with many observations. The six group model however, was the first to identify an upward trajectory. While the seven group model outperformed the six group model on statistical grounds, substantively the seven group model added little besides further subdividing the trajectory group showing a steep downward slope based on the number of posts in the initial months of members' posting careers. For reasons of parsimony, we therefore chose the six group model to summarize our data. We also found that models using quadratic terms to capture developments in members' posting behavior outperformed models using cubic terms. Hence, we present the trajectories from the six group, second order model. To test the robustness of these findings, we re-ran the GBTM analyses on another nine random 10% samples. These analyses showed that for these additional samples, the increase in model fit when adding trajectory groups showed a pattern highly similar to that of the original 10% sample, as did the shape and level of the trajectories distinguished.¹ Hence, we conclude our findings to be robust in this respect.

Figure 4.7 Trajectories based on the frequency of total monthly posts per month since first post



¹ The results for the analysis on the additional 10% samples are highly similar to those found on the first 10% sample, with two exceptions. First, in a number of samples the four or five group solution failed to converge. As the six and seven group solution always did, and BIC values indicated that the six group model is preferred over simpler models, this does not affect our conclusions. Second, while in all samples a high frequency group is detected, the shape of this trajectory depends on the maximum number of months individuals allocated to this group have been observed. In a number of subsamples, the 'managers' trajectory is based on individuals who were observed for only 25-30 months of the maximum 49 month follow up, and consequently does not show a decline in the frequency of posts during the second half of the maximum observation period.

Figure 4.7 depicts the six trajectories distinguished in our data. Again, like in Figure 4.6, the x-axis represents the number of months since the first post on the forum. Note that the y-axis depicts the estimated number of monthly posts on a logarithmic scale. Table 4.4 provides descriptives for the posting careers of each of the distinguished trajectory groups.

The largest group of forum members ($N=883$, 58.8% of the sample) shows very little forum activity. With an average of 2.07 total posts per member of which on average 1.61 post in the 'General cSEM' category, for many in this trajectory their obligatory introduction post seems the only registered activity on the forum. Members allocated to this trajectory enter the forum during its later stages (average month of first post is March 2014), and mostly refrain from posting shortly after that (average posting duration of 0.10 months). Given that this still leaves 9 months of observation, the short duration of these members' posting career does not seem an artefact of the forum being taken offline. Given their failure to regularly contribute to the forum's content, these members would have quickly lost access to most of the forum and hence could be labeled 'Lurkers'.

The group we label 'Browsers' ($N=136$, 9.1%) shows a trajectory that in many ways is similar to that of 'Lurkers'. Members allocated to this group typically enter the forum in its later stages, and show a limited number of posts. Still, their average number of posts (10.1) is almost five times higher than that of 'Lurkers' and also includes posts under the 'Girls hardcore' category. Additional to their initial registration and application to the forum, it is likely that the majority of this group has at least shown some forum browsing (yet non-communicating) activity for a relatively short period of time. Again, it seems likely that many members in this category quickly were given the status 'inactive member' for not meeting the obligatory posting frequency.

With on average 19.0 posts, the third trajectory distinguished shows a less steep decline in posting frequency than both 'Lurkers' and 'Browsers' and an average posting duration of nearly six months. In line with the overall finding that posting diversity goes up with posting frequency (Figure 4.5), we find the posting careers of this group to be more versatile in nature. Over two thirds (68%) of the members allocated to this trajectory posts under the 'Girls hardcore' topic at least once, while 26% show at least one post under the 'Boys hardcore' category. One in five members allocated to this trajectory also contributes to the 'General discussion' pages of the forum. Over half of the members in this category are registered as 'full members' by the forum administrators, suggesting that they contribute to the forum on a regular basis. We label this group, that constitutes 11.1% of the sample ($N=167$), the 'cSEM interested' group.

The trajectory we label 'Escalators' ($N=237$, 15.8%) shows an increase in posting

frequency the longer members are active on the forum. Given the timing of their last post, were the forum not taken offline, many members in this trajectory likely would have continued to contribute to the forum. In terms of the nature of their posts, this group mirrors the 'Browser' group, in that about one in four (26.6%) of their posts falls under the 'Girls hardcore' topic. When we break down the average number of posts per topic per month active on the forum, we find no clear trend in the gravity of the cSEM as indicated by the forum topics (hardcore versus softcore). One in ten of the members allocated to the 'Escalator' group has a VIP status. As VIP status heavily depends on posting activity, the desire to reach VIP status may partially drive the escalating trajectory.

Fifth, 'Vested [cSEM community] members' (N=67, 4.5%) first become active already during the early stages of the forum's evolution. With an average of 152.4 posts, they rank among the most frequently posting groups. Nine out of ten (93%) of 'Vested members' post in the 'Girls hardcore category', while 81% contribute to the 'General discussion' topic signaling their affinity with the cSEM community as a whole. 'Vested members' are the only group of whom some members have been actively posting since the start of the forum, though their average posting career length does not differ from 'Escalators'. The large majority of members allocated to this category enjoys a 'full member' status (suggesting that they meet the posting requirements attached to this role), and 20.9% even has VIP status.²

Finally, a small (N=12), but nevertheless significant group we label 'Managers', is characterized by a posting frequency (1,636) that dwarves that of the other groups by factor 10 at the minimum. All of the 'Managers' contribute to the 'General discussion' topic (13% of their posts is dedicated to this topic), while three quarters post under the 'Information and technical safety' topic. Members in this group show the longest posting career, and half joins the forum prior to May 2013. Over half (58.3%) of the 'Managers' has an 'Administrator' or 'VIP' status.

When interpreting the trajectories, it is important to keep in mind that our data are right-censored, and that not all members could be observed for the same time period (since their first post). The 'Vested member' trajectory for example, shows a downward slope with increasing posting career length. This indicates that with time since first post on the forum, the public communication of members allocated to this group declines. This in turn may result from these members increasingly switching to private chat environments, or these members switching to other fora,

² A VIP status is assigned by the forum administrative team to those members who actively participate in the community by sharing their knowledge and by sharing (new and unique) cSEM. Only a small minority of forum members gets assigned this VIP status, and it might give this group access to the restricted and more private sub-fora.

perhaps in an effort to acquire new CSEM material. It could also reflect an actual decline of these members' Darkweb CSEM related activity. Given that many members allocated to this group only become active during the latter part of the forum's evolution, it must be kept in mind that the estimates for the posting trajectory for this trajectory are based on a decreasing number of members. Hence, the latter part of the trajectory increasingly depicts the trajectory of members that were among the first to enter the forum.

Finally, to examine the association between the period in the forum's evolution, and the distribution of members' posting trajectories, we cross-tabulated group membership by a variable indicating whether these trajectories were initiated during the 'start-up' period or during the 'fully functional' period. Fisher's exact test ($p < 0.001$) revealed a significant association between group membership and period, with 'Lurkers' making up a larger proportion of members during the 'fully functional' period. Given the low number of posts for this category, this is unlikely to be merely an artefact of the censoring of the data.

Table 4.4 Descriptives per trajectory group

	Lurkers	Brow- sers	CSEM interes- ted	Escala- tors	Vested mem- bers	Mana- gers	Brown- Forsythe	Sign.	Welch	Sign.
N	883	136	167	237	67	12				
%	58.8	9.1	11.1	15.8	4.5	0.8				
month first active	39.92	38.57	38.49	37.63	37.07	26.92	12,607	***	12,841	***
month last active	40.01	40.51	44.46	48.25	47.67	47.67	194,321	***	608,732	***
duration	0.10	1.93	5.96	10.62	10.60	20.75	222,875	***	546,098	***
diversity^a	0.17	0.43	0.50	0.58	0.62	0.70	136,531	***	123,203	***
# members posting										
CSEM general^b	0.94	0.94	1.00	0.99	1.00	1.00				
girls hardcore	0.08	0.54	0.68	0.78	0.93	0.83	195,028	***	275,673	***
general discussion^b	0.03	0.26	0.20	0.41	0.81	1.00				
boys hardcore	0.03	0.19	0.26	0.41	0.60	0.83	55,705	***	64,728	***
girls softcore	0.03	0.26	0.31	0.50	0.66	0.75	65,383	***	80,723	***
restricted areas	0.00	0.01	0.04	0.12	0.43	0.67	28,835	***	21,592	***
boys softcore	0.01	0.09	0.17	0.27	0.42	0.58	27,758	***	33,163	***

	Lurkers	Brow- sers	CSEM interes- ted	Escala- tors	Vested mem- bers	Mana- gers	Brown- Forsythe	Sign.	Welch	Sign.
information and technical safety	0.06	0.04	0.08	0.12	0.42	0.75	20,797	***	13,285	***
mean # posts										
total	2.07	10.10	18.96	38.08	152.42	1636.17	5,747	***	62,174	***
CSEM general	1.61	4.40	7.15	14.77	43.67	544.58	2,536		40,374	***
girls hardcore	0.17	2.43	3.71	10.14	44.24	220.58	9,398	***	52,710	***
general discussion	0.07	0.73	1.95	2.93	11.10	220.00	3,432	**	10,121	***
boys hardcore	0.07	0.81	2.72	3.70	22.49	133.33	4,360	**	17,775	***
girls softcore	0.04	0.96	1.47	3.32	15.52	116.92	2,958		15,880	***
restricted areas	0.00	0.10	0.51	0.97	6.79	95.00	4,116	**	4,981	***
boys softcore	0.03	0.57	1.32	2.01	7.34	224.58	1,724		9,033	***
information and technical safety	0.08	0.11	0.11	0.24	1.25	81.17	1,198		2,434	**

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

a Diversity computed across entire posting career, only for careers with at least two posts

b Robust test of equality of means can not be computed as at least one group has zero variance

4.4 Discussion

First, the current study quantitatively examined the evolution of a Darkweb forum dedicated to the exchange of CSEM, and supportive of adult-child sexual contact in general. This particular forum was active for over four years before it was shut down by law enforcement. During the latter 16 months the forum was operational, it morphed from a relatively secure and hidden forum, into an open forum each month attracting hundreds of new members and members adding between 20,000 and 30,000 posts to the forum website. A development that seemed instigated by a change in the forum's management, and that likely contributed to the forum's eventual demise. Though selected in part because of its size and focus and therefore not representative for the total population of Darkweb CSEM fora, these figures help to fathom the scope of the problem of online CSEM.

At the same time, these figures add nuance. While viewing and downloading CSEM are clearly illegal, and the continuous demand for CSEM creates a similarly continuous supply, the reverse also seems true, such that the sheer presence of CSEM on the internet tempts a serious number of individuals to enter a CSEM dedicated Darkweb

forum out of curiosity rather than out of a fully developed sexual interest in under-aged children. For over one third of the membership of the forum under scrutiny here, their posting is limited to the mandatory post needed to (temporarily) gain access to the CSEM forum.

Next, we took both Quayle and Taylor's (2003) model of problematic internet use, and Lanning's (2001) typology of online CSEM offenders as theoretical vantage points, to further scrutinize variation in the different dimensions of the longitudinal sequence of individual's forum posting behavior. Motivated by curiosity and opportunity, situationally motivated normal adolescents/adults were predicted to show a late onset (with regard to the forum's establishment, rather than to the offender's calendar age), low frequency and short duration of their posting 'career' (hypothesis 1). Corroborating the findings on the skewness in individual posting frequency, results of the GBTM identify a trajectory, comprising over half of the forum members, that is characterized by exactly these features and whose posting 'career' on the forum seems to end more or less where it begins. The posting behavior of these 'Lurkers' therefore fits with what could be expected from Lanning's 'Normal adolescent/adult' type.

Preferentially motivated pedophiles are expected to show posting careers that are early onset, high frequency and long duration, and besides posts on sexual topics, contain posts indicating an interest in CSEM community building (hypothesis 3). The trajectory we labelled 'Vested members' seems to best fit Lanning's 'Pedophile' type. These forum members are frequent contributors to the forum's content, and regularly submit posts to both sexual topics, and topics of a more 'social' nature. These members' posting trajectory and formal forum status signal their vested interest in the forum and the CSEM community as a whole. Given their most recent activity on the forum is temporally close to the forum's closure, 'Vested members' would likely to have continued their offending given prolonged opportunity.

Both the 'Morally indiscriminate' and the 'Diverse' offender type were predicted to show a pattern of posting behavior falling somewhere in between that of 'Normal adolescents/adults' and 'Pedophiles' (hypotheses 2 and 4). Two trajectories, those we labeled 'Browsers' and 'CSEM interested' meet these criteria. Within the limits of the available data however, neither of these trajectories shows clear signs of a more diverse sexual interest compared to the other trajectories. Members on the 'CSEM interested' trajectory are also socially active on the forum, which does not fit either the indiscriminate or diverse type, positioning them closer to 'Vested members' in that respect. Additional information about members online pornography use (e.g. activities on different legal and illegal pornographic websites) collected during police investigations, or content analysis of their forum posts, could help to differentiate indiscriminate from diverse online CSEM offenders.

The trajectory we labelled ‘Escalators’ combines a late onset with an increasing posting frequency. As with the ‘Vested members’ we find no reason to assume these ‘Escalators’ were to discontinue their forum behavior any time soon had the forum not been shut down. The posting trajectory displayed by these members fits that of Lanning’s ‘Latent offender’ type (hypothesis 5), with the exception that members of the escalating trajectory do not engage much in the ‘General discussion’ topic. Hence, this trajectory seems to better fit the disinhibitory effect of merely accessing cSEM described by Quayle and Taylor’s (2003) model of problematic internet use.

Finally, our GBTM analysis distinguishes a group of forum members whose posting behavior diverges widely from that of the other members in terms of onset, frequency and duration, and does not seem to readily fit any of the types in the Lanning typology. We labeled this group ‘Managers’ because their posting behavior does not seem to primarily result from their own sexual interests, but rather from the managerial tasks these members have taken upon themselves in order to keep the cSEM forum up and running. In some ways, this trajectory mirrors Lanning’s (2001) ‘Profiteer’ type, or Elliott and Beech’s (2009) ‘Commercial exploitation’ type, in that being an administrator of a Darkweb forum is perceived as ‘a full-time job’, requiring much more forum activity than that required to fulfill private goals. Importantly however, while supervising a Darkweb cSEM forum may provide ‘Managers’ with certain benefits, these benefits do not seem to include monetary profits. Like ‘Vested members’ therefore, ‘Managers’ extensive involvement with the cSEM community, is likely driven by a definite sexual preference for children characteristic for the ‘Pedophile’ offender type (Lanning, 2001).

4.4.1 Limitations

Linking the observed posting trajectories to existing offender typologies rests on the assumption that posting behavior reflects member’s motivation and sexual interest. Other factors may however help shape members’ forum behavior, like the availability of material that suits members’ sexual interests, the user friendliness of the forum, the responsiveness of the forum’s management and fellow members to technical questions or substantive requests, or their willingness or ability to submit themselves to the posting regime of the particular forum. It should also be kept in mind that individuals may simultaneously visit and be member of more than one Darkweb cSEM forum, and that their behavior may differ on each of these fora. Reconstructions of online behavior are therefore never completely accurate measures of sexual interests and motivation (Brennan & Hammond, 2017; Fortin & Proulx, 2019).

Aside from this more general caveat, a number of limitations specific to the current study need mentioning. First, as mentioned in the method section, the available data

only covered publicly posted forum communications and we have no way of estimating the size and nature of any private communications going on between members. Private communications however typically initiate from public interactions, so, while likely underestimating the frequency of total forum communication, public posts may still accurately reflect the topics discussed. Furthermore, only when the ratio between public and private communications were to differ between member types, would this influence the rank ordering of the trajectories distinguished.

Second, unlike previous studies (Fortin & Proulx, 2019; Taylor et al., 2001), ours did not include an assessment of the actual CSEM exchanged or collected through the forum's website. Rather, we relied on categorizations made by the forum's administrators to typify the topics of the posts analyzed. While our findings are in line with results from previous studies, for example with regard to the popularity of CSEM depicting underaged girls over that of CSEM depicting underaged boys (Fortin & Proulx, 2019), the crude distinction between 'softcore' and 'hardcore' may have limited our ability to detect trends in the severity of members posting careers, and hence adequately test assumptions regarding habituation and escalation of offending behavior over time.

Third, our data were right-censored. This means that especially for those becoming first active on the forum during the latter part of the observation window, the observed trajectory may not reflect the entire posting career. While GBTM is designed to handle missing data, adding measurements – i.e. additional months – may alter the shape of the trajectories identified. Hence, we remain uncertain of the extent and nature of continued forum activity for the vested and escalating groups. Our view of the cycle of managerial turnover is also limited. That said, for the most prevalent trajectories the time between the last known post and the forum being taken down is such that we can safely conclude, especially against the background of this particular forum's mandatory contribution policy, that many members following these trajectories are no longer active participants in the forum.

Finally, distinguishing trajectories using GBTM is best viewed as a way of reducing the complexities of observational data by collapsing these complexities within a limited number of trajectories. While these trajectories may aid further interpretation of Darkweb CSEM members forum behavior, their theoretical relevance depends on the extent to which these online communication patterns can be linked to theoretically derived variables that may explain both their prevalence and developmental pathway. To further assess the bearing these trajectories have on the Lanning (2001) typology for instance, would require research that combines behavioral measures – like forum posting – with measures of sexual motivation. Retrospective, longitudinal analysis of online offenders' CSEM collections, matched with survey measures of sexual interest,

treatment file information, and records on offenders' previous sexual and nonsexual transgressions, would be a fruitful avenue of future research in this respect.

4.4.2 Future research avenues and implications

Despite these limitations, the current study adds to a budding literature analyzing the online behavioral patterns of those who use the internet to commit sexual offenses (e.g. Brennan & Hammond, 2017; Hammond et al., 2009; Taylor et al., 2001). While various typologies of online sex offenders have been offered, few offer the detail needed to derive precise hypotheses on the behavioral patterns to be expected for each of these types. The current study, and other studies applying a criminal career paradigm to online CSEM offending (Fortin & Proulx, 2019; Westlake & Bouchard, 2015), will probe theorists of sexual offending to further refine their explanations and incorporate concrete and testable expectations in their models. While the current analysis reconstructed forum members' communication patterns in a posterior fashion, future research could also assess the extent to which it is possible to predict members' future forum position, based on the development of their online communications. In this way, interventions could be designed aimed at curbing members' developmental pathway and preventing their online offending from spiraling out of control.

Apart from implications for future academic theory and research, the results of the current study may aid professional practice. Quantitatively charting the behaviors of online CSEM offenders can assist law enforcement in targeting specific fora or specific (groups of) forum members for further (qualitative) assessment and intervention. On the forum level, research indicates that the total volume of traffic on a forum predicts its persistence (Westlake & Bouchard, 2015). Fora showing an increase in communications, like the one studied here, therefore demand prioritization. On an individual level, member profiles can inform investigators which offenders to target for undercover operations, and on how to approach them taking into account their offending motivation. Different Darkweb forum members may also require different interventions to prevent them from future offending. Whereas situationally motivated lurkers and browsers may be deterred from CSEM offending by increasing their perceived risk of exposure and prosecution, vested members and managers – given their vested interests in the CSEM community – likely are not, or to a much lesser extent. This knowledge is not only informative to law enforcement, but also to clinical-forensic professionals in assessing offenders and offering them the most effective treatment with the aim of reducing future offending.

Appendix

Table A1 Criteria used for assessing GBTM model fit

# groups	order	BIC (obs) N=16,455	BIC (ind) N= 1,502	AIC	LL	Estimated group probability (π_j)						
						grp 1	grp 2	grp 3	grp 4	grp 5	grp 6	grp 7
1	2	-16,934.74	-16,931.15	-16,923.18	-16,920.18	100.0						
2	2	-11,682.76	-11,674.38	-11,655.78	-11,648.78	70.2	29.8					
3	2	-11,103.13	-11,089.96	-11,060.73	-11,049.73	20.6	64.5	15.0				
4	2	-10,879.3	-10,861.35	-10,821.49	-10,806.49	16.1	62.0	4.3	17.6			
5	2	-10,842.25	-10,819.51	-10,769.02	-10,750.02	11.1	16.5	12.4	55.8	4.2		
6	2	-10,809.92	-10,782.39	-10,721.27	-10,698.27	11.2	4.4	12.0	55.9	1.2	15.3	
7	2	-10,803.4	-10,770.72	-10,698.98	-10,671.98	11.4	3.9	2.9	55.8	1.2	15.0	9.8
1	3	-16,485.32	-16,480.54	-16,469.91	-16,465.91	100.0						
2	3	-11,586.84	-11,576.07	-11,552.16	-11,543.16	70.3	29.7					
3	3	-11,097.92	-11,081.16	-11,043.96	-11,029.96	20.3	64.9	14.8				
4	3	-10,86.69	-10,863.94	-10,813.46	-10,794.46	17.9	15.6	62.0	4.4			
5	3	-10,867.93	-10,839.2	-10,775.43	-10,751.43	9.0	14.1	61.8	1.9	13.3		
6	3	-10,842.79	-10,808.08	-10,731.0	-10,702.0	8.1	10.7	56.4	1.8	10.5	12.5	

Note Additional indicators of model fit (Nagin, 2005) for the 6 group model:

$2(\Delta\text{BIC})$ approximates the logged Bayes factor, values > 10 indicate the more complex model is preferred

AvePPj > 0.7 for all groups (0.81; 0.76; 0.76; 0.94; 0.98; 0.79)

OCCj > 5 for all groups (34.2; 67.9; 23.8; 13.0; 3281.3; 20.6)

Pj - π_j small for all groups (2.1; -0.1; 0.8; -2.9; 0.4; -0.5)

Average posterior probabiliy of assignment (AvePPj)							
grp1prb	grp2prb	grp3prb	grp4prb	grp5prb	grp6prb	grp7prb	2(ΔBIC)
.9917348	.9828731						10,503.96
.8796656	.9858674	.9324765					1,159.26
.817657	.9802669	.8883356	.8718029				447.66
.8116903	.8328345	.779667	.9419771	.8973085			74.1
.8119631	.7579809	.7639651	.9428063	.9761599	.7882499		64.66
.8115411	.7504362	.7405008	.9412045	.9710648	.7674629	.7290794	13.04
.992196	.9791056						9,796.96
.8800361	.9857991	.9197945					977.84
.8633809	.8185469	.9798812	.8977453				422.46
.7946093	.7617594	.9782184	.8797509	.7633095			37.52
.7757446	.7637236	.9353699	.8592755	.7258472	.7191928		50.28

Table A2 Results of the GBTM model fit, comparing the 10% analysis sample to the remaining 90% of the total sample

Forum characteristic	not in GBTM	in GBTM	standardized difference
<i>N</i>	13,336	1,502	
%	89.88	10.12	
month first active	39.00	39.04	0.01
month last active	42.25	42.25	0.00
duration	3.25	3.21	-0.01
diversity^a	0.39	0.40	0.01
# members posting			
CSEM general	0.96	0.96	-0.01
girls hardcore	0.33	0.34	0.03
general discussion	0.16	0.17	0.05
boys hardcore	0.15	0.16	0.02
girls softcore	0.18	0.19	0.01
restricted areas	0.06	0.05	-0.05
boys softcore	0.09	0.10	0.04
information and technical safety	0.09	0.09	-0.01
mean # posts			
total	28.12	30.12	0.01
csem general	10.87	10.77	0.00
girls hardcore	6.03	6.07	0.00
general discussion	3.21	3.04	0.00
boys hardcore	2.39	3.07	0.03
girls softcore	1.90	2.43	0.02
restricted areas	1.75	1.28	-0.02
boys softcore	1.24	2.65	0.04
information and technical safety	0.75	0.81	0.00

a Diversity computed across entire posting career, only for careers with at least two posts