

The SECI model and darknet markets: Knowledge creation in criminal organizations and communities of practice

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Marie-Helen Maras 

John Jay College of Criminal Justice, City University of New York, USA

Jana Arsovska

John Jay College of Criminal Justice, City University of New York, USA

Adam Scott Wandt 

John Jay College of Criminal Justice, City University of New York, USA

Melanie Knieps

University of Zurich, Switzerland

Kenji Logie 

John Jay College of Criminal Justice, City University of New York, USA

Abstract

This study examines darknet markets through the lens of a business theory on knowledge management. Taking epistemological and ontological dimensions into consideration, this study uses Nonaka's (1991) SECI model as a theoretical framework to identify and describe how tacit and explicit knowledge is created and shared on Silk Road, Pandora and Agora darknet markets, and how people affect this process. By studying this process, insights can be obtained into darknet market criminal organizations and communities of practice and their impact on the continuity and resilience of illicit darknet markets. This project used data from the Internet Archive collection of

Corresponding author:

Marie-Helen Maras, Department of Security, Fire, and Emergency Management, Center for Cybercrime Studies, John Jay College of Criminal Justice, City University of New York, 524 W. 59th Street, Haaren Hall, Room 4331 I, New York, NY 10019, USA.

Email: mmaras@jjay.cuny.edu

publicly available darknet market scrapes between 2011 and 2015 from Branwen et al. (2015). We observed instances of the SECI model (socialization, externalization, combination, and internalization) on darknet markets in both criminal organizations and communities of practice. Darknet market leaders and groups facilitated both knowledge creation and sharing. This study is the first to test the SECI model on darknet markets. The study provides an understanding of the complexity and resilience of darknet markets, as well as valuable information to help guide law enforcement agencies efforts to stop the illicit trade of goods and services.

Keywords

SECI model, knowledge creation, darknet markets, Silk Road, Pandora, Agora

Introduction

In an economy where the only certainty is uncertainty, the one sure source of lasting competitive advantage is knowledge. (Nonaka, 1991: 96)

The most resilient criminal enterprises are those able to adapt to market fluctuations, criminal competition and law enforcement action. This resilience is evident in darknet markets (DNMs) (Maras, 2017). DNMs are criminal enterprises, with an identifiable structure and core leadership and assigned roles for its members (e.g. administrator, moderator, vendor and buyer), where the number and types of roles vary across DNM sites (e.g. *United States v. Ross Ulbricht*, 2014; *United States v. Alexandre Cazes*, 2017). DNMs also have rules that must be followed by members, actively enforce these rules and punish noncompliance (*ibid.*). Within DNMs, significant criminal activity occurs, such as the illegal sale of drugs, weapons, malware, hacking services, stolen data, and counterfeit documents, money and goods (UNODC, 2021).

Unlike legitimate organizations that can defend themselves against competitors and law enforcement action with legal remedies, criminal enterprises do not have these means at their disposal. Given that DNM members need to constantly adapt to internal and external threats to illicit markets and new technological developments, it is no surprise that DNMs and their discussion forums have been described as a 'shared repository of knowledge' (Martin, 2014: 69) especially regarding issues of operational security like the effective concealment of illegal goods in shipments, delivery of intangible illicit goods and services and the preservation of privacy and anonymity on DNMs. Because this 'shared repository of knowledge' on DNMs has not been the focus of studies, this article explores if and how knowledge is shared and managed in this virtual environment.

To accomplish this research objective, DNMs are examined through the lens of business theories – namely, knowledge management theories. Because criminal organizations and their operations have often been likened to organizations in the legal economy (Maras, 2017), we argue that the use of theoretical frameworks originating from the business literature is a good fit for DNM research. Thus far, knowledge creation, an essential element of knowledge management (Dul, Ceylan, and Jaspers, 2011), has not been previously identified and studied on DNMs. In our analysis, we focus on formal and informal paths to knowledge creation. The formal path involves knowledge created within the criminal organization and maintained by it. The informal path involves knowledge

created and maintained by communities of practice (CoPs), ‘groups of people informally bound together by shared expertise and passion for a joint enterprise’ (Wenger and Snyder, 2000: 139). By studying this process, insights can be obtained about DNM criminal organizations and CoPs and their impact on illicit darknet markets. In view of that, analyzing three historic DNM sites – Silk Road, Pandora and Agora, this article examines DNM knowledge creation and sharing through the lens of the SECI model, one of the most well-established knowledge management theories.

Knowledge management

Knowledge management (KM) is generally described as ‘a process of creating, acquiring, capturing, aggregating, sharing and using knowledge, wherever it resides, to enhance organizational learning and performance’ (Ungaretti and Tillberg-Webb, 2011: 47). Over the years, the KM framework has been used to explain the role of knowledge in a variety of industries, including automotive (Carlile, 2004), biomedical (Swan et al., 2007) and healthcare (Nicolini et al., 2008). However, KM has never been used as an analytical framework to examine how knowledge is created and shared in DNM criminal organizations and CoPs. This is surprising given that criminological scholars acknowledge the significance of knowledge creation and sharing among criminal groups (Kwon et al., 2020).

The SECI model

One of the most influential and widely cited references in the KM field is Nonaka’s (1991) SECI model. Unlike most models’ sequential, evolutionary path (for a summary, see Farnese et al., 2019), Nonaka equates the knowledge creation process to a spiral where knowledge is generated through a continual dialogue between the (a) *epistemological* dimension, where two types of knowledge (tacit and explicit) interact with each other, and (b) *ontological* dimension, where people who create knowledge within a team, organization and/or inter-organizationally, interact with each other. In a never-ending process, knowledge is ceaselessly created, amplified and practised according to the SECI model (Nonaka and Takeuchi, 1995).

The epistemological dimension. Organizations seek ways to identify employees’ knowledge and make it available to others. Put simply, they seek to make tacit knowledge explicit. Tacit knowledge is highly personal, context specific and deeply rooted in individual experiences, ideas, values and emotions (Nonaka, 1994). Given that tacit knowledge develops from experiences and actions that reside as know-how within individuals, it is often not easily accessible. This type of knowledge is shared among people through the process of socialization, personal communications and interactions (Dalkir, 2011). In contrast, explicit knowledge is systematically documented know-how within an organization. Since explicit knowledge is formally articulated and shared by individuals, it can be easily accessed and organized through tools such as publications, computers or artifacts that help express, share and store knowledge (*ibid.*). The SECI model proposes

that knowledge is created through a continuous interaction between both types of knowledge.

Although earlier scholars understood tacit knowledge as incommunicable (Polanyi, 1966), Nonaka viewed new knowledge as both the product of previous knowledge creation phases as well as the starting point of subsequent ones. Scholars like Polanyi (1966) argued that ‘we can know more than we can tell’; however, Nonaka and Takeuchi (1995) noted that tacit knowledge could be portrayed as ‘words or numbers that anyone can understand’ (9). Simply stated, according to Nonaka we could ‘tell what we know’. Moreover, Nonaka did not think of tacit and explicit knowledge as co-existing separate entities (like Polanyi). Having been ‘inspired by but not restricted to Polanyi’s work’ (Nonaka and von Krogh, 2009: 648), Nonaka and others conceptualized tacit-explicit knowledge along a continuum, where knowledge can potentially have both tacit and explicit dimensions. Pure tacit and explicit knowledge lie at the far ends of the spectrum; everything in between includes knowledge with both tacit and explicit dimensions, the extent of which depend on its place in the continuum. As Nonaka and von Krogh (2009) noted, the ‘process of moving towards the explicit knowledge side of the continuum allows us to express certain aspects of our tacit knowledge’ (642). In view of that, ‘verbalized and externalized knowledge’ is not ‘necessarily ... completely explicit’ and knowledge captured in writing is not necessarily explicit (Panahi, Watson and Partridge, 2016b: 548).

The ontological dimension. What makes the SECI model unique is its appreciation of the role people play in the knowledge creation process. The interaction between tacit and explicit knowledge in the epistemological dimension takes place in the ontological dimension through interactions between individuals (I), among team members (T), within the organization (O) and within the environment (E) (Nonaka and Takeuchi, 1995) (see Figure 1). New knowledge is created through the dynamic interaction between the epistemological and ontological dimensions.

The SECI process. The SECI process describes how the ontological and epistemological dimensions interact in four phases – socialization, externalization, combination and internalization – to create new knowledge (see Figure 1).

1. *Tacit to tacit knowledge.* Before knowledge can be shared, it must be articulated by those who hold it. The verbalization of tacit knowledge can be achieved through *socialization* (i.e. ‘disseminating tacit knowledge is another key aspect of socialization’; Nonaka and Konno, 1998: 43). During this process, individuals’ subjective knowledge is accumulated, shared through daily interaction, and socially justified by coalescing and expanding it.
2. *Tacit to explicit knowledge.* Through *externalization*, tacit knowledge is transformed into explicit knowledge. One way to covert knowledge is to make a hidden concept or mechanism explicit through the sequential use of analogies and models. Documenting and summarizing tacit knowledge is a central feature of externalization.

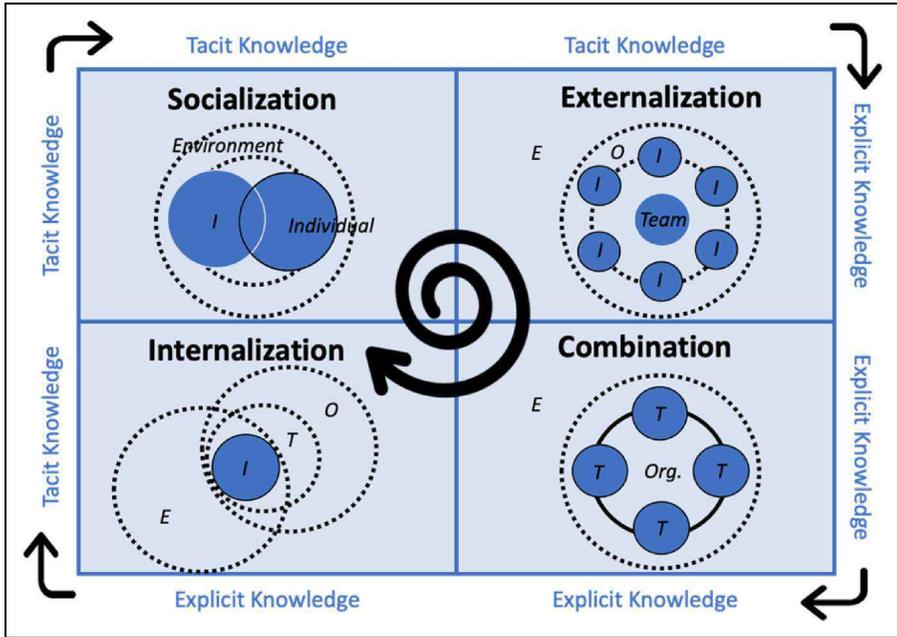


Figure 1. The updated SECI model.

3. *Explicit to explicit knowledge.* In the *combination* phase, explicit knowledge that emerged in the previous phase is combined and organized with different types of explicit knowledge collected from inside and/or outside the organization (e.g. computerized communication networks and large-scale databases). Once this knowledge has been edited (e.g. by aligning it with the philosophy of the organization or CoP), more complex and systematic explicit knowledge can be formed and disseminated to members of the organization.
4. *Explicit to tacit knowledge.* *Internalization* occurs when individuals reflect on the new external knowledge created in the previous phase and apply it to their specific environment (e.g. through training-on-the-job or learning-by-doing). The new knowledge, therefore, is used in real-life situations and manifests in new practices and routines. Once new tacit knowledge emerges from the application of the explicit knowledge, the SECI process begins anew and initiates further conversions of knowledge.

The environment (ba). Knowledge creation and sharing does not occur in a vacuum but requires a specific context where it can be contextualized. Context endows meaning to what would otherwise remain mere information. The effort to synthesize knowledge with other people through the forging of relationships and human interaction constitutes the essence of *ba*, which roughly means *place* and is ‘the shared context for knowledge creation’ (Nonaka et al., 2000: 8) - ‘a platform where knowledge is created, shared, and exploited’ (Nonaka et al., 2001: 19).

In 1998, Nonaka and Konno already associated the *combination stage* of the SECI model with a virtual space (i.e. *cyber ba*). Specifically, they spoke of virtual collaborative platforms and databases as places where existing explicit knowledge is combined and synthesized to create new explicit knowledge. They also introduced concepts relating to other spaces that supported knowledge sharing and creation in the socialization (*originating ba*), externalization (*integrating ba*) and internalization phase (*exercising ba*). Nonaka and Konno (1998) were open to new contexts and ways in which knowledge can be shared. For them, ‘the key platform of creation is the “phenomenal” place. Such a place of knowledge can emerge in individuals, working groups, project teams, informal circles, temporary meetings, e-mail groups, and at the front-line contact with the customer’ (Nonaka and Konno, 1998: 41). The *ba* that they describe is not necessarily a physical space – it can be physical, virtual, or mental; when these spaces coincide or connect, they ‘form a “greater ba,” known as “basho”’ (*Ibid.*).

ICT. The role of information and communications technology (ICT) in KM in organizations where employees are not physically co-located but are required or need to share knowledge is explored in literature (albeit in a limited manner). The findings of studies on the role of ICT in supporting tacit and explicit knowledge creation and sharing and the extent to which this occurs are mixed. Specifically, the findings vary in regards to the type (i.e. email, apps, instant messaging, video conferencing, wikis, blogs, e-learning platforms, information repositories, virtual reality and social media) and number of ICT found to facilitate tacit and/or explicit knowledge creation and sharing and/or vary in finding support for one or more SECI model phases (Lee and Kelkar, 2013; Panahi et al., 2016b; Hildrum, 2009; Mueller et al., 2011; Lopez-Nicolas and Soto-Acosta, 2010; Bunk et al., 2019).

Virtual communities of practice. While the exploration of the role of ICT in KM is important given its integral role in virtually all personal and professional activities, ICT alone cannot deliver it. As McDermott (1999) rightly pointed out, ‘to leverage knowledge...[the] focus... [needs to be] on the community that owns it and the people who use it, not the knowledge itself’ (McDermott, 1999: 110). Online communities or virtual CoPs (VCoPs) share interests and knowledge, socially interact, collaborate on mutual issues and concerns and discuss problems. In VCoPs, ‘repeated interactions, the possibility to ask contextualizing questions, the validation of answers, the mutual challenging of partial answers, the presentation of an idea, and its further refinement through dialogue gradually shape participants’ comprehension of what is going on’ (Faraj et al., 2016: 676). VCoPs are not bound to a specific organization, but some, most or even all members could be part of an organization. VCoPs can be made up of individuals within geographic, physical proximity, individuals who are geographically distributed and/or a combination of both. According to Bartolacci et al. (2016), ‘VCoPs should not be seen as a technical environment alone’ but ‘as virtual contexts in which knowledge creation takes place’ (797). Therefore, as community-based, virtual platforms, DNMs are an especially interesting case for expanding the SECI model.

Our study: rationale, methods and approach

Our study is the first study to apply Nonaka's SECI model to DNMs. In line with the rationale of this framework, we adopt a holistic approach to knowledge creation taking both the epistemological dimension (tacit, explicit) and ontological dimension (individuals, groups and organization) into consideration. While the SECI model has been identified in various organizational contexts, it remains unclear how it manifests within criminal settings. In view of that, our research questions are:

1. How is knowledge on DNMs created (epistemological dimension)?
2. How do people affect the knowledge creation process (ontological dimension)?

Our research markedly differs from previous KM research whose data was commonly derived from questionnaires, surveys, interviews, focus group studies and case studies (see literature cited in section on knowledge management). To reduce the possibility of confounding factors, we selected popular DNMs active before major market disruptions following the law enforcement takedown of AlphaBay and Hansa in 2017: Silk Road (2011–2013), Pandora (2013–2014) and Agora (2013–2015). These DNMs were chosen for (a) their prominence and success, (b) their built-in discussion forums containing substantial communication threads and posts and (c) their exclusive accessibility through the darknet.

We used archival data obtained from the Internet Archive from Branwen et al.'s (2015) collection of DNM scrapes. This publicly available dataset (<https://www.gwern.net/DNM-archive>) contains approximately 125 + darknet marketplaces and forums collected between 2011 and 2015. The DNMs we analyzed had built-in discussion forums, guided by moderators, administrators and/or members, which allowed: members to troubleshoot issues (e.g. payment and nondelivery); discuss new DNM site features and topics of interest, such as security, products, services and best practices; and exchange information about vendors and DNM markets, among other things. We only analyzed DNMs with archived discussion forums. These discussion forums only contained data that was available at the time of Branwen et al.'s (2015) data collection. For this reason, we excluded incomplete discussion forums and threads from our sample. Concerning the inclusion criteria we used for the discussion threads analyzed in our study, we included examples that: (1) illustrated the way knowledge is created and transferred within both DNM criminal organizations and VCoPs; (2) were rich and varied in content and context; and (3) were based on complete discussions (e.g. were not missing significant portions of the discussion).

Even though archival data comes with limitations, such as those relating to the verification of the methods used to archive data and the completeness of data, this level of scrutiny is unnecessary for our study. The purpose of our work is to identify DNM knowledge creation and transfer, not to quantify its occurrence. Due to the limitations of our dataset (e.g. several discussion forum threads were missing portions of the conversation, ended abruptly and/or were not completed during the time of the capture), quantifying instances of knowledge creation and sharing would not produce meaningful results. Our research aims to identify *if* knowledge creation and sharing occurs on DNMs and

describe how knowledge is created and shared, using examples from DNM discussion forums and threads. It *is not* concerned with identifying *the extent of* knowledge creation and sharing and generalizing findings.

Using Nonaka's SECI model, we focused separately on the theory and the four phases of the SECI model (i.e. socialization, externalization, combination, internalization). For internal validity purposes, we took steps to ensure that our analysis was grounded in the SECI model. For example, we resolved questions regarding demarcations between the four phases with respect to one another and discussed how each phase relates to DNMs. We reviewed Silk Road, Pandora and Agora discussion forum threads and posts and identified examples of knowledge creation and sharing, particularly as it relates to each SECI model phase and the entire SECI model process. We reviewed and discussed identified threads and posts for accuracy and consistency in findings.

DNM findings

Knowledge creation on DNMs (almost) exclusively takes place in an online environment. By scrutinizing the existence of the epistemological and ontological dimensions in this virtual space, we examine how the SECI model applies to DNM knowledge creation. The goal *is not* to identify all instances of the SECI process on select DNMs, but rather to determine whether it *is* identified on DNMs. Our findings do not present an exhaustive and complete list of incidents, as this is beyond the scope of our study, but provide examples, in each phase, of knowledge creation, how knowledge is created (epistemological dimension) and how people affect this process (ontological dimension).

Socialization

Socialization is the process whereby tacit knowledge is shared and new tacit knowledge is created through social interactions. Social interactions can and have taken place online. In their study of tacit knowledge sharing on social media platforms, Panahi et al. (2016b) observed that knowledge communicated in discussions and chats via social media resembled unstructured informal discussions and conversations in face-to-face interactions that are often observed during the socialization phase of the SECI model (548). These unstructured informal discussions and conversations also take place on DNM discussion forums. Consistent with the work of Battistoni et al. (2011), we examined DNM members' unstructured and informal social interactions in discussion forums (i.e. responses to existing posts and the posing of questions to other DNM members) to identify instances of tacit knowledge sharing and creation.

Epistemological dimension. Our review of Silk Road (SR), Pandora and Agora revealed that they served as socialization spaces where tacit knowledge was shared interpersonally in unstructured chats. By exchanging personal experiences, people informally discussed different issues and/or tried to find solutions to problems. The observed chats were often unfiltered and had grammatical errors.

Members shared and created new knowledge through informal discussions on community forums embedded in these three DNM sites. These exchanges covered a range of issues and topics. Common DNM threads were inquiries about drug use (e.g.

'Other ROAs [Route of Administration] for #4 [heroin] (no IV)?') and manufacturing (e.g. *'Fentanyl cuts?'*). Here, knowledge is shared to solve problems or improve practices. For example, two SR members engaged in one-on-one conversation about *'How to package mushrooms for shipping?'*, where one member started a discussion thread (*'I think I need a vacuum packaging. Or maybe shrink packaging? But i have no idea how to do it. Because even cheapest device for it is pretty expensive. What do?'*) and another member provided an answer (*'Save your money. If you intent to sell on SR, you will NEED a food grade vac sealer, at the very least For the time being, buy some cheap moisture barrier bags on ebay. Use a house hold iron to seal them'*). The member who posed the original question expressed gratitude, posted an image of a bag and asked a follow up question to ensure that the solution proposed was understood (*'Thanks! Should i use bags like this?...''*). The responding member confirmed that the bag in the image would suffice and shared further knowledge on packaging, relevant tools and associated costs (*'Yes, that will do. You NEED to get a vac sealer. You don't have to spend a stack on an industrial one. Bottom of the line FoodSaver, \$60 bucks, will suffice. Just be sure to seal each pack multiple times. Smell is permeable threw each bag with in 24hrs typically'*). DNM members also engaged in brainstorming (*'Would it be possible to randomize one's own profile addresses? Because LE could just copy the popular vendors profile.onion address now before anyone has a chance to go stealth, also any customer could leak the address to the public. It would be ideal to be able to switch up.onion addresses at will, then update customer base'*) and reflected on responses (e.g. *'Hmmm. This sounds like a good idea in theory, but in practice I fear it may alienate some of the potential good customers out there...'*).

Social interactions also served to establish and maintain values such as loyalty, commitment, dedication, concern for others, non-violence and respect. For example, an SR member started a thread about the participation of an ex-vendor in a TV interview about SR (*'Australia – Channel 7 News – Today Tonight – SR Customer INTERVIEWED'*). This thread led to a vivid exchange between several members who expressed their opinions and displeasure about the interview. While some expressed the desire to punish the *'traitor'* (*'... this guy deserves to catch a massive beating!!'*), others called for restraint to avoid playing into the narrative (mis-)characterizing the DNM community as violent criminals (*'Dudes, shut the fuck up any implied threats ... The first time real violence is traced to SR, we will see real attacks on the site'* or *'What really infuriates me is that the media can not or have not distinguished the difference between Silk Road and the Tor browser so many articles insinuate that SR is linked with Child Porn, Gun running etc'*). This example illustrates how socialization not only functions to share practical knowledge (about drug use and production) but also provides meaning to the group by endorsing non-violent values.

Ontological dimension. Individual community members clearly play a fundamental role in DNM knowledge creation and sharing. Their focus on collective learning and security-related issues suggests a strong commitment to the DNM community. This finding is in line with recent research showing that DNM members constitute a VCoP, which works towards a shared common goal (Kwon et al., 2020). For example, when SR administrator Dread Pirate Roberts (DPR) proposed an intervention that would allow vendors to hide using a new *'stealth mode'* feature, some criticized it for being

against SR's fundamental libertarian values ('*this is a step towards encouraging a "private market" mentality which goes against all that SR stands for*'; '*We are purporting to be proponents of the "Free Market" ... This is clearly not the case if reputed/reliable sellers withdraw from the public market.*').

Externalization

Externalization is the process of turning tacit knowledge (e.g. work experience, skills, etc.) into explicit knowledge so that it can spread more easily through organizations or other KM platforms (Nonaka, 1994). Knowledge is codified by 'capturing' individual tacit knowledge and 'translating' it into explicit knowledge for the group (Nonaka, 1991; Nonaka and Takeuchi, 1995). The product of this phase is new theoretical knowledge.

Epistemological dimension. SR, Pandora and Agora members often relied on personal experiences when proposing possible solutions to security concerns. Conversations were often initiated by members seeking input from the DNM community. Members responded by making suggestions and providing summaries of ongoing discussions about specific topics. For example, in a discussion about secure communications (*Security/Threema, an end-to-end encrypted messaging App (WhatsApp alternative)*), one SR member said, '*I'm trying to spread the word: everybody should ditch WhatsApp and use Threema instead [because] everything you send through Threema (text, voice, images, videos) is encrypted on your phone.*' Similarly, in a thread on secure operating systems (*Full Tutorial – Installing Tails LiveUSB with a Persistent Volume*), an SR member shared a tutorial and a description about *Tails (The Amnesiac Incognito Live System)* which '*helps you to use the Internet anonymously.... It is a complete operating-system designed to be used from a DVD or a USB stick independently of the computer's original operating system. It is free software...that is being constantly updated for security flaws.*' In response, hundreds of member posts were made about Tails over a seven-month period (January 2013-July 2013). These posts enabled SR members to learn more about this operating system through the insights and experiences of community members. The fact that these posts remained in the forums long after the discussion ended preserved the explicit knowledge these conversations generated, making it readily available to future members concerned about their privacy and security.

Another common strategy to externalize knowledge involved making references to solutions that were useful on forerunner DNMs. A case in point involves one Pandora member who reached out to the community about how to set up software to use PGP keys, which encrypts message-based communications and authenticates members' digital identities ('*I went to sourceforge.net and downloaded the portable PGP. My question is that when I send a message I jsut cut and paste that whole paragraph string of weird letters into the body of the message and the recipient can decipher it*'). Replying to this post, group members provided feedback and shared their experiences. Many made references to other DNMs (e.g. Sheep, BMR and SR) to provide examples of success stories. In other words, past events holding valuable lessons in a different, though related, situation (on other DNMs) were offered to serve as templates to solve the specific issues of Pandora's members.

Ontological dimension. Knowledge creation on DNMs is predominately driven by community members. They not only frequently initiate discussions involving other individuals but also make direct requests to higher ontological levels. For example, one Pandora member voiced displeasure about the DNM site's feedback editing feature and requested changes: '*This is a lesson that was learnt at SR and Sheep... I cannot believe you are making the same mistake again. Buyer must be able to edit feedback, it is absolutely crucial in order to discover who the scam vendors are... Please fix this.*' This example illustrates how DNM members directly call on administrators, who constitute the highest ontological level on DNMs, to make improvements. While the SECI model predicts that individuals drive the conversation in the externalization phase, it does not account for a direct interaction between them and the organization.

Our review revealed that administrators' direct responses to member-driven discussions are relatively common. For example, in a Pandora discussion forum about removing scammers who use shill feedback to appear trustworthy, Pandora's admin 'Alice' noted that '*Showing buyer trade count is a MUST! EDIT: Even better would be to only count feedback from buyers that already have a reasonable amount of FINISHED trades (like 5)... But some feedback trust score can be added to show how trustworthy feedback actually is. This is probably only way how good feedback can be calculated.*' Alice's responsiveness to Pandora members' concerns showcases the habitualness of direct interactions between higher and lower ontological levels. Even more, administrators seem to play a vital role in synthesizing the members' experiences and reflecting about possible solutions, thereby contributing to the creation of theoretical knowledge. DNM members and administrator(s) interactions are noteworthy because, according to the SECI model, these ontological levels typically do not directly reach out to each other. Indeed, it would be odd in corporations to see direct interaction between customers and organizational leaders.

Combination

Combination is the process of collecting explicit knowledge from inside and outside the organization to combine and edit it into more complex and systematic sets of explicit knowledge at the organizational level (Nonaka, Toyama and Konno, 2000). Through the merging and diffusing of information throughout the organization, the combination phase produces systematic knowledge that can include changes of existing practices, policies and/or norms. This process, which predominantly involves the higher levels of an organization (e.g. top management and leadership), can help improve the available knowledge for the entire organization.

Epistemological dimension. The combination phase on SR, Pandora and Agora often resulted in the creation of new or updated manuals, tutorials, best practice guides and DNM site features. The former (written) types of explicit knowledge like the *Seller's Guide* and *Buyer's Guide* are usually stored in dedicated areas and are equally available to members from all user groups. New DNM site features are usually disseminated in site-wide update sections or via announcements from moderators or administrators in user help and discussion forums. For example, SR operator and administrator DPR created a new site feature in response to buyer requests for an easier way to access their favourite

vendors ('You can now become a fan of your favorite vendors and bookmark the items you purchase the most From a vendor's page, click "become a fan" and from an item page click "bookmark this item." When you do, they will appear at the bottom of your homepage for easy reference. Enjoy!'). Like in physical settings, ICT plays a crucial role as a data repository in the creation and sharing of explicit (systematic) knowledge.

Ontological dimension. Our analysis provides further evidence affirming the significance of VCoPs on DNMs. A case in point are the improvements made to Pandora's 'User Feedback' system. As a result of discussions between members of all ontological levels encompassing buyers, vendors, moderators and the administrator (Alice), the leadership made changes and improvements. A Pandora moderator posted, 'Hey guys, You may have noticed that Alice wasn't active on Forum for a few days, he was busy coding and improving Pandora. Here are some new features he integrated...NEW feedback System...More Stuff coming soon.' The new knowledge in this example included a customer feedback system that enabled vendors to attribute feedback to specific buyers by allowing them to see the monikers of buyers providing feedback.

Although many outputs of the combination phase resulted from the actions of higher ontological levels like the site administrator, VCoPs also directly drove knowledge creation without any action from higher level administrators. For example, Agora contained a dedicated section for 'Guides and eBooks.' Agora members had the opportunity to update the section by adding new guides that updated and consolidated knowledge from all parts of the site. These guides contained information needed to buy and sell drugs on Agora, including updated information on using PGP to secure communications and a consolidated guide to counterfeiting currency. Hence, lower ontological levels were explicitly encouraged to contribute to the consolidation efforts occurring on this DNM. One Agora member who claimed to have a PhD in organic chemistry even offered to write new guides for anything Agora VCoPs needed ('Do any vendors need their labs "enhanced" with a bit of my professional experience? ... Any particular synthesis? I can also offer advice. Such as what to do when coming down from MDMA or other drugs'). Again, this finding was inconsistent with the SECI model, which only assumes involvement of individuals in the socialization and internalization phase (Nonaka and Takeuchi, 1995). Rather, our analysis revealed that individual community members also played a crucial role in the creation of systematic DNM knowledge during the combination phase.

Internalization

The internalization phase is characterized by new operational knowledge resulting from the application of explicit knowledge. Without a clear link to a source of explicit knowledge, the shared insights arising from this learning-by-doing process can easily be misclassified as empathic knowledge that typically emerges in the socialization phase. Indeed, both phases deal with tacit knowledge expressed by individuals. However, only operational knowledge can be traced back to a source of explicit knowledge that has previously been shared throughout an organisation and subsequently manifested in individual behavioural changes or 'aha' moments (Nonaka and Takeuchi, 1995).

Epistemological dimension. Our analysis indirectly revealed that some SR, Pandora and Agora members developed new operational knowledge based on explicit knowledge put forward in the combination phase. Rather than identifying the internalization process directly, we were able to identify the effects of this process in discussion posts. The effects of this process were observed in the shift in member practices in the means used to identify themselves on DNMs (i.e. the use of PGP rather than monikers as identifiers). Some member comments described successful implementations of the new feature (e.g. setting up their own PGP key and verifying a vendor through their PGP key) whereas others described failed attempts (being unable to add the PGP key to their vendor profile, issues with the updated list of verified vendors, etc.). Through learning-by-doing, they made and described new experiences, which suggests that they developed new tacit (operational) knowledge in response to previously introduced explicit (systematic) knowledge.

Another example involved an SR member, who raised a concern about the deletion of discussion forum threads (*'Why are so many threads being deleted without explanation?'*). This post sparked numerous replies, even promoting a conspiracy theory that government agencies were deleting posts. Eventually, an administrator mentioned that members who started threads could delete them. One member tested this by attempting to delete a thread. Once successful, the member reported findings in the thread, providing the steps taken to delete the thread (i.e. clicking on a 'remove topic' button) and results of the member's actions (thread deleted and obstacles encountered for specific thread deletion). The members and others – such as the originator of the thread, had an 'aha' moment that original members who posted the threads could have deleted them (*'Oh I didn't realize it was still possible for people to delete their own threads. That is probably what happened in at least some of the cases...'*).

A further example that illustrates the internalization of DNM practices and norms concerned the use of stealth. Many forum discussions and vendor guides deal with improving methods to evade authorities' detection of packages. By advertising the quality of their stealth and by signalling receptiveness for feedback, a Pandora vendor demonstrated the internalization of these practices and norms (*'I think [my quality of stealth] is pretty decent at the moment. I've been researching more advanced ways (misdirection) to ship and I know it will get better. If you think my packaging sucks, I would rather you not troll and PM (with PGP) instead. Helpful guidance will not go unrewarded if it ends up being my status quo. Just saying'*). This example illustrates how the explicit knowledge about stealth on Pandora can be linked to (a willingness for) behavioural change.

Ontological dimension. Internalization is generally indirectly observed on DNM forums as a response to the administrator's implementation of new site features or policy changes affecting the market's operation. DNM leadership therefore plays a decisive role in this phase. The effects of internalized knowledge observed on SR were also evident on other DNMs. For example, references to SR's libertarian ideology that was significantly shaped by DPR also emerged on Pandora (*'I've been here since Silkroad started ... I've been there right along with you fighting for a free market ... I've always strived for quality and safety, and do not plan on giving up anytime soon!'*). The persistence of these values further supports the notion that DNM members constitute VCoPs that work with passion towards a shared common goal. As

Table 1. Main findings of our review per actor (criminal organization, community of practice and combined) and SECI phase (socialization, externalization, combination, internalization).

Actors	Socialization		Externalization		Combination		Internalization	
	Tacit to tacit	I → I	Tacit to explicit	I → G	Explicit to explicit	G → O	Explicit to tacit	O → I
Criminal organization	<p>Knowledge:</p> <ul style="list-style-type: none"> - <i>Empathic:</i> Informal discussions about security (protection of privacy, integrity, authentication, etc.), drugs (use, production, potency), vendors (responsiveness, product quality, identity) and community (values and codes of conduct) lead to an exchange of experiences and perspectives. 		<p>Knowledge:</p> <ul style="list-style-type: none"> - <i>Theoretical:</i> Individual users as well as administrators synthesize experiences shared by users. Externalization occurs through reflection about possible solutions, including references to forerunner DNMs. 		<p>Knowledge:</p> <ul style="list-style-type: none"> - <i>Systematic:</i> Knowledge is formally codified in new/ updated manuals, practices, norms, policies and site features that are informed by user feedback and other external and internal sources. 		<p>Knowledge:</p> <ul style="list-style-type: none"> - <i>Operational:</i> In response to formal changes of explicit knowledge by the criminal organization, individual buyers and vendors develop new operational knowledge. Internalization manifests in changes in behaviour and aha moments evident in the shared experiences shared by DNM users following a new policy, practice, or site feature. 	
	<p>Interaction:</p> <ul style="list-style-type: none"> - Direct interactions between users like vendors and buyers (individual to individual). 		<p>Interaction:</p> <ul style="list-style-type: none"> - User (I) starts a conversation with DNM community (G). - Interactions between users (I) and administrators (O) relatively common. 	<p>Interaction:</p> <ul style="list-style-type: none"> - Knowledge creation involves groups (G) and the organization (O) consisting of higher ontological levels like moderators and administrator. 		<p>Interaction:</p> <ul style="list-style-type: none"> - From an organization (O) to an individual (I) 		

(Continued)

Table 1. (Continued)

Actors	Socialization		Externalization		Combination		Internalization	
	Tacit to tacit	I → I	Tacit to explicit	I → G	Explicit to explicit	G → O	Explicit to tacit	O → I
	<p>Platform:</p> <ul style="list-style-type: none"> - Socialization can be observed in feedback on vendor profiles, personal messages and threads on forum. <p>Example:</p> <p>Individual buyers provide feedback about purchases from vendors, disclosing information about delivery and packaging: 'Product offers/USA uncut tan MDMA - intro pricing: Shipping- was pretty good for small sample would like to see maybe a vacuum seal just I and maybe a piece of something to conceal but everything else looked legit nice printed label! Product- it was amazing i never thought i was gonna</p>	<p>Platform:</p> <ul style="list-style-type: none"> - Externalization can be observed in forum threads, conversations in chat groups (e.g. vendor roundtable) and personal messages <p>Example:</p> <p>In response to feedback of this kind, vendors may start threads on DNM forums asking buyers to refrain from disclosing too much information: 'VENDORS WHO TAKE THEIR STEALTH SERIOUSLY: Please be careful with these sorts of posts. Any vendor who ends up on a list like this is certain to get closer attention from LE...; EVERYONE Please STOP saying you got X from Y vendor okay in Z time! This type of unnecessary behavior feedback allows for profiling of vendors and countries and if you have</p>	<p>Platform:</p> <ul style="list-style-type: none"> - Combination can be observed in forum threads, announcements and changes on DNM Website (feature, policy, norm). <p>Example:</p> <p>In response to forum conversations, DNM administrators may introduce a new site feature allowing vendors to use stealth mode to hide from the general marketplace: 'DPR/Stealth Mode: Stealth mode allows you to run your business out of view of the general public. Whether your sales are growing faster than you can expand your infrastructure to keep up, or you just don't want to be in the public eye any more and are happy with the size of your current customer base, stealth mode might be the solution for you. When activated, your listings will no longer appear in public searches, category</p>	<p>Platform:</p> <ul style="list-style-type: none"> - Internalization can be observed in forum threads, vendor profiles, buyer feedback and behaviour. <p>Example:</p> <p>In response to formal changes, buyers and vendors may share their experiences with the changes: 'I have been thinking a change like this is the next evolution. I feel bad for the new users that can't get now on the upper tier of buying, but I really like the peace of mind of getting to know those I am serving. And this is a solution that keeps me in business. I was more wanting to have a "subscriber list" for each listing. Where each listing I can specify if it is open, or only available to one or more users. I might have an open listing or</p>				

(Continued)

Table 1. (Continued)

Actors	Socialization		Externalization		Combination		Internalization	
	Tacit to tacit	I → I	Tacit to explicit	I → G	Explicit to explicit	G → O	Explicit to tacit	O → I
Community of practice	hardly roll off such a small amount split it between me and my gf and it was super strong 30 mins later i was rolling hard 45 minutes later i was super trashed the most ive ever been with out taking 8 or 10 pills in a night! communication- great responded quickly and was nice and kind in responses [...]		any questions about a vendor ask the vendor, a well-known forum member, or use your brains and read the vendors profile review on the forums!		views, or any pages linked to from the public site [...].		something small, and then when I trusted a user, I might add them to some of the more expensive listings...??	
	Identical to Criminal Organization		Knowledge: - Theoretical: Only individual DNM users synthesize the experiences shared by users. Externalization of knowledge occurs through reflection about possible solutions, including		Knowledge - Systematic: Knowledge is informally codified in new/ updated recommendations (practices, norms) that are informed by user feedback and other external and internal sources		Knowledge: - Operational: In response to non-binding informal suggestions of explicit knowledge by members of the VCoP, individual buyers and vendors develop new operational knowledge. Internalization manifests in changes in	

(Continued)

Table 1. (Continued)

Actors	Socialization		Externalization		Combination		Internalization	
	Tacit to tacit	I → I	Tacit to explicit	I → G	Explicit to explicit	G → O	Explicit to tacit	O → I
			references to forerunner DNMs.				behaviour and aha moments evident in the experiences shared by DNM users.	
	<i>*Identical to Criminal Organization*</i>		<p><i>Interaction:</i></p> <ul style="list-style-type: none"> - User (I) starts a conversation with DNM community (G). 		<p><i>Interaction:</i></p> <ul style="list-style-type: none"> - Knowledge creation only involves individuals (I) and groups (G) which together form the VCoP. 		<p><i>Interaction</i></p> <ul style="list-style-type: none"> - From a VCoP to an individual. 	
	<i>*Identical to Criminal Organization*</i>		<p><i>Platform:</i></p> <ul style="list-style-type: none"> - Externalization can be observed in forum threads, conversations in chat groups and personal messages. 		<p><i>Platform:</i></p> <ul style="list-style-type: none"> - Combination can be observed in forum threads 		<p><i>Platform:</i></p> <ul style="list-style-type: none"> - Internalization can be observed in forum threads, vendor profiles, buyer feedback and behaviour. 	
	<p><i>Example:</i></p> <p>A good reputation is vital for DNM vendors who traditionally used monikers as identifiers. Using the monikers of</p>		<p><i>Example:</i></p> <p>Given the risk of misappropriation of a reputable vendors' monikers, DNM users express concerns regarding the validity of identity claims and offer</p>		<p><i>Example:</i></p> <p>In the combination phase, users may consolidate solutions to verify vendors' identities: 'Hi guys, I have setup a little page that allow you to search feedbacks from BMRv3 (and more to come),</p>		<p><i>Example:</i></p> <p>In response to formal changes, individual buyers and vendors may share their experience with the changes: 'Seems pretty good, never ordered from you on BMR</p>	

(Continued)

Table I. (Continued)

Actors	Socialization		Externalization		Combination		Internalization	
	Tacit to tacit	I → I	Tacit to explicit	I → G	Explicit to explicit	G → O	Explicit to tacit	O → I
Actors	well-known vendors who are active on other DNMs can help to establish a new customer base when expanding to new DNMs: 'Hello Psychonauts I am a high-quality psychedelics vendor who has been around for a while (Atlantis/ Sheep/BMR/ITM) so some of you should know me or recognize my name...'		alternative verification methods: 'This is a scam in the making. This post above is part of the setup. Going to bet now that the DutchMagic that appears on [advertising not allowed] is not DutchMagic but a scammer impersonating him; Actually, no it's not a scam. The only thing you need to do is verify our PGP key. We have used the same key on SR, Sheep, BMR and now [advertising not allowed [...]...'		using the vendor PGP key. http://fayfyq2iznsob.onion/index.php A little note about this: NEVER TRUST A USERNAME !!! ALWAYS SEND A PGP ENCRYPTED MESSAGE TO CHECK IF VENDOR IS THE SAME !!! ...'		myself but might try it now on Pandora :) (careful with the PGP key you posted above, pocketscale: for some reason there's an extra carriage return after each line - if people copy paste it, an import into their wallet may fail because of it)	
	Combined	Observations: - Unlike physical settings, tacit knowledge can be captured more easily on virtual platforms. - Knowledge creation	Observations: - Contrary to the SECI model, direct interaction between individuals (DNM users) and the (criminal) organization (DNM	Observations: - When moderators and administrators (O) do not participate in knowledge creation, individuals (I) share their insights with the rest of the group (G) directly. This	Observations: - Although operational knowledge is difficult to capture in virtual spaces (Chalkiti and Sigala, 2008), our data set provided			

(Continued)

Table 1. (Continued)

Actors	Socialization	Externalization	Combination	Internalization
	Tacit to tacit → I	Tacit to explicit → G	Explicit to explicit G → O	Explicit to tacit O → I
	always starts with the socialization phase (regardless of the ontological levels involved in subsequent phases).	administrators) can take place.	observation showcases the significance of the VCoP in the knowledge creation process on DNMs.	evidence for its existence on DNMs. - The persistence of community values supports the notion that individuals on DNMs constitute a VCoP that works with passion towards a shared common goal.

proposed by the SECI model, individuals play a crucial role in this phase. Through their active engagement with the site's practices, policies and norms (e.g. reviewing manuals or guides, participating in forum discussions, buying and selling products and services), new tacit knowledge is created that resides within DNM members. Although operational knowledge is difficult to capture in virtual spaces (Chalkiti and Sigala, 2008), our analysis of these sites provided evidence of the effects of internalization on DNMs.

In summary, we observed instances of all phases of the SECI model either directly or indirectly on DNMs, wherein knowledge spiralled through criminal organizations and VCoPs (see Table 1 below for a summary of the processes, our observations and examples of each SECI model phase).

Discussion

The purpose of this research was to explore the usefulness of the SECI model as an analytical lens in the context of knowledge creation on DNMs. Our analysis, which identified instances of knowledge creation and sharing on SR, Pandora and Agora, resulted in three main findings. First, we observed instances of all four SECI model phases, including the *epistemological dimension* (tacit or explicit knowledge) and the *ontological dimension* (individual, group and organization). Second, as showcased by VCoPs central role in knowledge creation, DNMs organizational hierarchy appeared to be less steep than proposed by the SECI model. Finally, distinguishing between the four SECI model phases is more difficult in virtual than physical settings. The model provided the framework that allowed us to conduct a more systematic analysis of the various dimensions involved in the creation of knowledge, both on their own as well as in conjunction.

Epistemological dimension

The knowledge shared and created on SR, Pandora and Agora covered a broad spectrum. As expected, the sharing of explicit knowledge maintaining the security of the sites and VCoPs like manuals, DNM site features (e.g. stealth mode, PGP) and security-enhancing software (e.g. Tails and Threema) was commonplace. Also noteworthy was the prevalence of knowledge sharing concerning experiences (know-how) and practices (day-to-day activities, routines and guidelines). Overall, there were direct or indirect indicators of each phase in our DNM data.

While previous studies note that tacit knowledge was difficult (Nonaka and Takeuchi, 1995) or even "impossible" (Polanyi, 1966) to capture, these studies were conducted in brick-and-mortar organizations whereby tacit knowledge was directly communicated from one person to another orally through informal social interactions of persons in co-located geographic locations. While *the originating ba*, which supports socialization, was originally conceptualized as a physical space wherein geographically co-located individuals engage in face-to face conversations and socialize (Nonaka and Konno, 1998), subsequent studies revealed that virtual platforms could serve as places for *socialization* and tacit knowledge creation and sharing (Mueller et al., 2011; Battistoni, Pasqualino and Moscetta, 2011; Panahi et al., 2016a, 2016b; Bartolacci et al., 2016).

Our study is consistent with these studies, which show that physical proximity might not be as essential for knowledge creation in the socialization phase as previously thought. Our observation of knowledge creation in the socialization phase on DNMs contradicts Nonaka and colleagues earlier work that emphasized face-to-face interactions in this phase (Nonaka and Takeuchi, 1995).

Knowledge is shared through feedback on vendor profiles (e.g. to communicate experiences and opinions about product quality) and through DNM forum posts. Individuals may also socialize outside of DNMs. In fact, we observed this in a post where members were asked to participate in brainstorming sessions outside of the DNM discussion forum (*'I'm starting a forum, and we need YOUR help in brainstorming. For more information, please join #nirvanaon IRC silcroadg3c3mtu6.onion Looking forward to seeing you there!'*). Individuals likely also interact through private messaging, but we cannot analyze these interactions because non-public data cannot be recorded and scraped.

The tacit knowledge created and shared on DNMs included opinions, experiences and know-how about illicit goods and services, and security practices, as well as emotions. From the DNM discussion threads and posts, it became apparent that members did not only seek practical knowledge but also emotional support and a sense of community. Because DNMs capture tacit knowledge in writing and all discussion threads and posts can be observed, this creates the false impression that one-to-one conversations do not occur, possibly resulting in their misidentification as a different SECI model phase.

DNM members articulation of explicit knowledge in the externalization phase was observed as well. Often as a response to comments (e.g. feedback, forum discussions), members made efforts to consolidate information and propose solutions. That is, they made tacit knowledge explicit through dialogue. Members of various DNMs also referred to examples of 'best practices' they encountered on forerunner sites such as Sheep, BMR and SR. Unsurprisingly, knowledge creation and sharing were particularly evident in the combination phase. This phase exclusively deals with explicit knowledge which can easily be captured and disseminated through ICT. Creating new systematic knowledge about stealth, encryption software, behaviour guidelines and other security-based know-how makes the operations on DNMs more efficient and secure. Although the sharing of systematic knowledge clearly plays a critical role in sustaining DNMs with knowledge to subvert law enforcement efforts, it is a balancing act. Disclosure of too detailed knowledge can be detrimental when it is reviewed by law enforcement who will use this information against them.

The internalization phase was identified by observing its effects. However, it was challenging to identify this phase because it shares some common features with other phases dealing with tacit knowledge. As all interactions occur on the same virtual platform allowing all ontological levels to intermingle, one must pay attention to the context in which a comment is made. Unlike socialization and externalization, internalization requires (a) a clear reference to explicit knowledge like a specific policy, practice, or norm that was introduced on the DNM site (regardless of who introduced it – i.e. administrator, moderator, vendor, or another community member), and (b) must convey a behavioural change or 'aha' moment in response.

Ontological dimension

Our research showed that knowledge creation predominantly involved the higher and lower ontological levels. This finding is in stark contrast to the significance Nonaka and Takeuchi (1995) attribute to the middle managers of an organization. In firms, middle managers play a key role in the knowledge creation process because they synthesize the tacit knowledge of both frontline workers and senior executives alike. By making this knowledge explicit, they help incorporate it into new products and technologies. The innate properties of virtual spaces where many interactions are documented in the feedback, comments and member forum posts may be partly responsible for this finding. Its relative longevity – together with the ease to establish contact with the higher organizational ontological levels – permeates hierarchical structures and facilitates information flow.

Like previous research, we observed that VCoPs played a vital role in the process. DNM members' shared interest as well as the feeling that they are part of a community are major drivers of knowledge sharing (Lave and Wenger, 1991). Similarly to legitimate corporations that have benefited from the social capital generated by their respective VCoPs (Sheng and Hartono, 2015), our research showed that DNM members also have an active role in the development of new products, services and practices in the illicit online economy. Prior knowledge sharing research revealed that individuals 'view their knowledge as a public good, belonging not to them individually, but to the whole organization' (Ardichvili et al., 2003: 69). This finding may shed some light on DNM resilience which – despite recurring market disruptions through law enforcement shutdowns, exit scams and cyberattacks from competitors (EMCDDA and Europol, 2017) – seem to recover quickly (van Wirdum, 2019). The commitment of VCoPs may be a reason why law enforcement actions have had minimal impact on DNMs (Décary-Héту and Giommoni, 2017). It is even possible that these actions might have taught them to adapt and become more resilient (Everton, 2012).

Ba and leadership

The setting in which knowledge creation and sharing occurs plays an essential role in the SECI model. In the few studies on the SECI model in virtual environments, the distance and anonymity virtual spaces create has largely been framed as a barrier to knowledge creation and sharing rather than an asset. On DNMs, the lack of personal contact is certainly one of the reasons why people interact on – not stay away from – these virtual spaces. Despite the lack of personal interaction, DNMs are a 'place' where individuals share experiences, best practices, feelings and emotions. DNM members clearly benefit from being able to share perspectives and experiences through social interactions without needing to compromise their anonymity.

Our findings revealed that DNM leadership and VCoPs enabled knowledge creation and sharing. Research demonstrates that leadership has a powerful effect on knowledge sharing (Politis, 2002). Politics (2002) noted that leaders are central to 'providing the vision and energy for knowledge sharing and to sustain effective knowledge management practice. Such leaders must contribute to the creation of a corporate knowledge culture

and a managerial mindset that promotes the flow of knowledge throughout the organisation' (194). Leadership can thus influence the atmosphere on DNMs. Our research showed that leadership on DNMs can generate an atmosphere that encourages knowledge sharing and creation. For example, many of the features of SR can be attributed to DPR's leadership. SR contained various features that incentivized knowledge sharing and creation that can be viewed using the lens of the SECI model, including a private message system (from individual to individual), a public discussion forum to discuss topics related to the SR (from individual to group), a support section to seek help from administrators directly when an issue arose (from individual to organization), and a 'wiki' to receive advice about using the site (from organization to individuals) (*United States v. Ross Ulbricht*, 2017). In discussions, SR members praised DPR and his ability to quickly respond to their ongoing needs and demands. His leadership encouraged VCoPs to continuously share knowledge because DPR always acknowledged and resolved their demands and concerns. Our review of discussions forums revealed that VCoPs expressed their satisfaction with DPR's ability to adjust the site, incorporate technology to protect VCoPs and take various viewpoints/experiences into consideration when developing new features and site updates. By welcoming suggestions and feedback from DNM members, DPR created a culture that encouraged the exchange of ideas and experiences. Specifically, he cultivated *ba* – a 'space of shared trust and common understanding' – on SR and a culture of knowledge sharing.

Limitations and future research

A main limitation of our study can be attributed to archival data we chose to analyze for our research. This data predominantly included English-language discussion forum threads (with a few exceptions, e.g. Dutch and German), although this focus is unsurprising given that English is often the lingua franca on DNMs. Even though we do not see a reason why knowledge creation and sharing would not also take place on non-English platforms, we caution against the premature generalization of our findings to other contexts. Furthermore, the use of archival data prevented us from controlling the data collection. Thus, it is not possible to verify the completeness of the data because we did not collect the data ourselves. Also, we were at times unable to determine the chronological order of events which prevented us from tracing prior or subsequent phases of the SECI model. Due to the richness of the data, however, it was possible to provide various examples that illustrate the SECI model phases separately, as well as the full SECI model spiral. Since the purpose of this research was to demonstrate the applicability of the SECI model to DNMs – not to quantify the SECI model phases and compare them on various platforms – this limitation does not diminish the significance of our findings.

Another limitation concerns the narrow opportunities for DNM social interactions. DNMs generate knowledge that is shaped by (a) the need for secretiveness, and (b) restricted communication channels. DNM knowledge sharing is thus likely restrained by the criminal nature of activities. Even if DNM members were willing to share knowledge, they would likely be restrained by the inherent limitations of interaction characteristics of virtual spaces. That is, unlike physical settings where knowledge creation can take place in informal interactions (e.g. during lunch, in the staff kitchen, during

commute), groups meetings (presentations, talks, conferences) and virtual platforms (email, video-conferencing software, etc.), the means of communication are less diverse on DNMs. This feature makes capturing and distinguishing between the SECI model phases challenging, especially where tacit knowledge is concerned.

Conclusion

Advances in ICT warrant a reconsideration of its role in knowledge sharing and creation, not only within the space of legitimate organizations and enterprises – the target of past studies, but also in criminal enterprises and VCoPs. Our study is the first to examine DNMs through the lens of a KM theory. Using the SECI model as our analytical framework, we identified its four phases on DNMs, and the contextual factors that enabled knowledge creation and sharing. We observed instances of tacit and explicit knowledge creation and sharing on SR, Pandora and Agora. Our research also supports the finding of a previous study demonstrating that VCoPs play an important role in DNM resilience and the illicit business they enable (Kwon et al., 2020). Though not totally immune to market disruptions, VCoPs are learning entities that have shown that they can recover from market shutdowns and transmit their knowledge to new marketplaces. Indeed, our study emphasizes the significance of the DNM VCoPs in sustaining illicit markets, which suggests that arresting individual members will hardly disrupt DNMs for long. It is possible that new DNMs will fill the void, as they have in the past (van Wirdum, 2019). Our study sheds light on the complexity and resilience of these illicit markets. The examination of DNM criminal organizations and VCoPs' KM process can provide valuable information to counter the persistence and expansion of these illicit markets. We believe our research serves as a useful starting point to inform and stimulate future research on DNM criminal enterprises and VCoPs.

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ORCID iDs

Marie-Helen Maras  <https://orcid.org/0000-0003-3428-4622>

Adam Scott Wandt  <https://orcid.org/0000-0001-8160-5519>

Kenji Logie  <https://orcid.org/0000-0001-7107-6510>

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