Actionability in a Situational Awareness world: Implications for social media processing system design

Julien Coche*

Centre Génie Industriel – Mines Albi

julien.coche@mines-albi.fr

Jess Kropczynski

University of Cincinnati

jess.kropczynski@uc.edu

Aurélie Montarnal

Centre Génie Industriel – Mines Albi

aurelie.montarnal@mines-albi.fr

Andrea Tapia

The Pennsylvania State University

atapia@ist.psu.edu

Frederick Benaben

Centre Génie Industriel – Mines Albi

frederick.benaben@mines-albi.fr

ABSTRACT

The field of crisis informatics now has a decade-long history of designing tools that leverage social media to support decision-makers situational awareness. Despite this history, there remains few examples of these tools adopted by practitioners. Recent fieldwork with public safety answering points and first responders has led to an awareness of the need for tools that gather actionable information, rather than situational awareness alone. This paper contributes to an ongoing discussion about these concepts by proposing a model that embeds the concept of actionable information into Endsley's model of situational awareness. We also extend the insights of this model to the design implications of future information processing systems.

Keywords

Actionable information, situational awareness, social media, crisis management.

INTRODUCTION

Crisis informatics, as a whole, aims at helping crisis responders by delegating a part of their workload to computers. To do so, many years of research led to the proposition of different systems or organizational recommendations to process social media data during crisis events. Emerging sources of data, such as social media, sensors in smart cities, or drones offer new research horizons. Many researchers have explored the value of information collected on social media to provide first responders the information that they need to respond. Supported by the rapid development of machine learning based techniques, several systems have been developed. (Vieweg 2012) presents social media content as a usable and valid source of information for decision makers during emergency events. At the same time, researchers such as (Verma et al. 2011) proposed to automate the processing of social media data for identifying relevant information.

Many systems have been then built, with a wide variety of features, to improve the Situational Awareness of the users. Noticing the lack of adoption of the systems created over the past decade by practitioners, researchers started to question the "situational awareness improvement" goal (Zade et al. 2018; Kropczynski, Grace, et al. 2018). (Zade et al. 2018) propose a survey and interviews of, mostly, practitioners with a manager role, whereas (Kropczynski, Grace, et al. 2018) fieldwork's focused specifically on 911 call takers. This questioning began from

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*corresponding author

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two observations presented in the aforementioned studies. First, the adoption of the proposed systems among practitioners is low. Secondly, practitioners, to a large extent, did not mention the need for Situational Awareness. Instead they emphasized on "identifying actionable information" as a primary information need from data collection efforts. Thus, the two previous articles propose refinements to the situational awareness paradigm. They define a new paradigm, actionability, that act as a criteria for incoming information: Is this information actionable for the first responder?

At the light of the previous findings, one can wonder the relationship between the concept of Actionability and Situational Awareness. This paper aims to further discussions in the ISCRAM community around the question: What is the position of the concept of Actionable Information in regard to the previous work on Situational Awareness in the design of social media data processing systems? The motivation behind this question is to further explore the initial problematic(s) of the domain, to then build systems that would better address responders needs. In order to initiate the discussions, the current article explores three aspects: (1) What are situational awareness and actionability? The literature review cover the previous propositions of definitions for both concepts and their evolution. (2) Are these two concepts separate from each other? In the third section, we argue, through a revision of Endsley's model, that Situational Awareness and Actionability are part of the same picture and both concepts are highly relevant for system design. (3) What does the consideration of actionability and situational awareness bring to the design of systems ? The last section builds on the previous two sections to propose principles to include in the development of systems that would benefit responders.

PREVIOUS WORK ON SITUATIONAL AWARENESS AND ACTIONABILITY

Conceptualizing Situational Awareness

Situational awareness is often described in simple terms as the understanding of the "big picture" of the situation. More precisely, it is the comprehension of the different aspects of an event, environment, and/or entities and how they are more likely to evolve in the near future. Sufficient situational awareness is a critical factor in decision making. Each individual has its own situational awareness, depending on several factors such as experience, perception ability, training etc. The group formed by individuals also carries its own situational awareness. In an emergency situation, decision-makers commonly find themselves in a rapidly changing environment and the availability and quantity of information may vary. Thus, tools that help to recover a sufficient situational awareness are of interest.

The currently dominant definition is seminal work presented in (Endsley 1995). Endsley, which proposes a definition of situational awareness as well as a model to explain how it fits into the decision-making process. She then defines situational awareness as the "perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future." (Kropczynski, Grace, et al. 2018, p.36) This definition is associated with three levels: (1) perception, (2) comprehension, and (3) projection. Perception refers to an operator's ability to detect relevant signals through the senses. Level 2, comprehension, refers to the ability to interpret and make connections between perceived signals. The last level, level 3, corresponds to the ability to anticipate future events based on available information. Figure 1 provides an overview of situational awareness in the decision-making process according to (Endsley 1995).

Numerous works in crisis informatics have extended this definition to meet the needs of this domain. (Vieweg 2012) thus uses the definition of (Endsley 1995) in that it tries to identify if the content of microblog contents can be useful during massive emergencies. The author therefore starts from a corpus of messages posted on Twitter during different events and identifies tweets that have the potential to improve situational awareness.

Later, (Verma et al. 2011) proposed to automate the processing of this information by natural language processing systems. Inspired by this proposition, several research teams built software to reproduce the results of Vieweg using computational automation. These systems aim to improve the user's situational awareness during mass emergencies. Many systems have been developed to classify tweets: (Caragea et al. 2011; Ashktorab et al. 2014; Imran et al. 2014). More recently, systems proposing a multi-modal approach (image + text) have been proposed. The multiplication of heterogeneous data collection channels is a promising approach. This approach enables systems to bring different points of view on the same event to the user. It also brings an interesting research perspective, especially when it comes to merging the two types of data. The combination of heterogeneous data sources can provide opportunities: (i) to collect more information (ii) to verify certain information when text and image overlap, and (iii) fill gaps in one information source with that of another.

Improving situational awareness is a common goal of many social media data aggregation systems and are espoused to address information needs first responders. Much progress has been made on information aggregation, processing, and analysis thanks to the work of these teams. However, given that these systems are not often utilized by
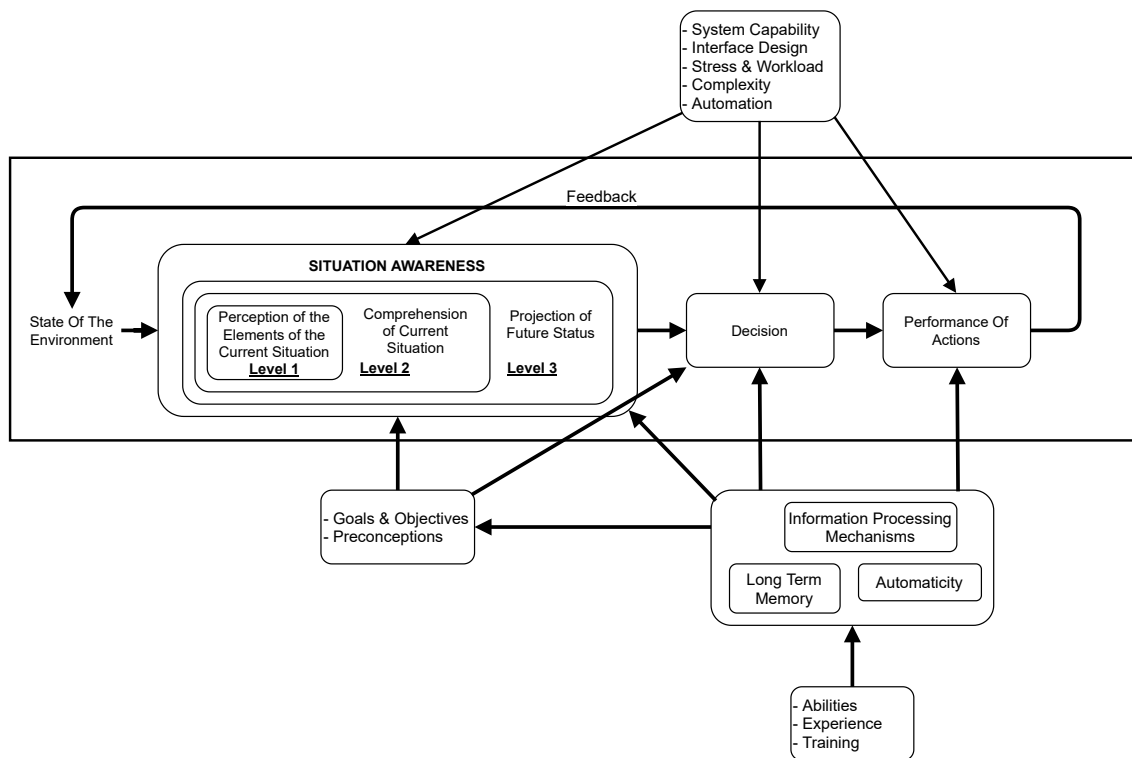
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Figure 1. Situational awareness model from Endsley 1995.

practitioners, we believe that enhanced situational awareness alone is unsatisfactory. Instead, evidence pointing to the need to consider other aspects of the information processing pipeline bears consideration in the development of new data systems.

Conceptualizing Actionability

As previously mentioned, fieldwork with crisis managers and operators of call centers found that situational awareness was not the primary information need of these practitioners (Zade et al. 2018; Kropczynski, Grace, et al. 2018) . Although this is the case, we are aware that depending on the nature of an incident a crisis management team can also find themselves lacking the information about the ongoing event necessary to take action, or on the contrary, flooded with information in a way that overloads person capacity to process information. Systems that process social media data can act as an additional source of information, so they help to cope with the first case. On the other side, when information is abundant, they do not necessarily provide the actionable information that emergency services need to plan a response. As a result, the issue of the relevance of the data provided should be given greater emphasis within systems design. This requires a proper definition of actionable information and a description of how it can be operationalized into system requirements.

During interviews with American emergency call centers' operators, (Kropczynski, Grace, et al. 2018 identified some of the criteria that would lead to what they refer to as a "golden tweet" or, a timely and actionable post to Twitter. Similarly to how they handle calls, 911 operators are looking for information that answer the 6Ws. These 6Ws are: *Where* is the assistance needed, *What* is the event taking place, *Weapon(s)* involved in the event (if relevant to the nature of the event), *Who* is involved in the event, *When* the event started, and in some cases information is collected regarding *Why* the event is happening. These specific questions help the call takers to acquire specific information that were identified has the most useful information to respond quickly and effectively an emergency—or in other words, to take action with regard to a particular event. Later, they refined the coding scheme they obtained in their 2018 article, with subcategories based on an analysis of how actionable information appears within actual social media posts during a crisis (Kropczynski, Halse, et al. 2019). At the light of this refined ontology, they coded 200 tweets and reported the proportion of tweets that were fitting in these categories. Their results show that among the tweets, four of the categories (Where, What, Who, Why) were significantly present, while two (Weapon and When) were rare.

Using a similar methodology, (Zade et al. 2018) conducted a survey and various interviews of emergency and humanitarian responders. They focused their research towards the question "how can the right information reach the

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right person at the right time?" In their approach to this research, they first asked practitioners to define actionability. (Zade et al. 2018) report "participants described actionable information as anything which either they or their organization could use at that moment to assist, enact, or expedite the solution to a (potentially) identified issue." More importantly, the authors report that the practitioners were using a definition according to their organizational role. More than definitions, the authors looked at the factors of actionability, and identified:

- Role of the practitioner

- Timeliness

- Location

- Credibility

- Context

They highlight some of the processes involved in actionability, namely (i) information verification, (ii) feedback adjusting the context of an action, and (iii) assessing quality and relevance of the information.

ACTIONABLE INFORMATION IN A SITUATIONAL AWARENESS WORLD

The way the authors perceive the previous definitions is as follows: a crisis situation happened when an unexpected and destructive event impact a community. This crisis event takes place in a given environment, in which first responders are deployed. Given the chaotic nature of the crisis, decision-makers are placed in an environment that is now unknown to them. They do not know what is or is not impacted by the event and what is the current state of the different elements/assets of their environment. In this context, the decision-makers see their situational awareness reduced to zero at the start of the event. As situational awareness is one of the first block to achieve decision-making, the decision-makers will try to rebuild their situational awareness. This start by recovering an adequate perception of the elements/assets of their environment (level 1 of SA). From that perception, they will use their skills/training to understand (level 2 of SA) the current situation and then evaluate the future status of their environment (level 3 of SA). In this picture, an actionable information is an information that can immediately trigger a decision from the decision-makers. For instance, they receive a report of an injured person. They can instantly decide to evacuate that person. However, if they didn't recover enough situational awareness yet, by not knowing safe places to conduct the evacuation, they might prefer to not consider this piece of information as actionable. While it is a useful and important piece of information, decision-makers have to delay their final decision on the evacuation. Only when they will have a sufficient perception of their environment they will be able to order the evacuation of the injured person. The following section details the reasoning that led to this vision of the relationship between Situational Awareness and Actionability.

Both the concept of Actionable Information and Situational Awareness are then linked to the concept of Information. Here, we use the definitions of Data and Information proposed by (Ackoff 1989) in his Data-Information-Knowledge-Wisdom framework. The concept of Data is an abstraction. It refers to symbols that have no meaning beyond their existence. Information on the other hand, is data that has been given meaning by the creation of connections between those points. Information generally answer questions such as "who", "what", "where" and "when". Thus, Information if what the caller takers interviewed in (Kropczynski, Grace, et al. 2018) are looking for through the 6W's framework.

Information and Data are also present in the Situational Awareness model proposed in (Endsley 1995). To the three levels proposed, and described earlier in the literature review, we can associate the Data-Information-Knowledge concepts as proposed in Figure 2.

The first level of Situational awareness concerns the perception of the "elements/assets" (or data) of the environment. Effective data collection allows a decision-maker to achieve a sufficient perception of the surrounding environment and a means to describe it. Assuming this first level is effective, the second level of Situational Awareness consists of being able to form patterns with the other elements/assets. Through the interpretation of the different data points and the way they interact with each other, the operator is able to understand the ongoing situation. This is this level of Situational Awareness that decision-makers are required to reach to be able to make decision. This is also this same level that is often lost during the chaotic nature of a mass emergency event, and that decision makers try to recover using situational awareness tools (Endsley 1995). The final level use the patterns known or identified by the decision-makers to make predictions on the future states of the environment, thus referring to the Knowledge layer of the framework. It is preferred that the decision-maker has this level of Situational Awareness, but it is not necessarily required.

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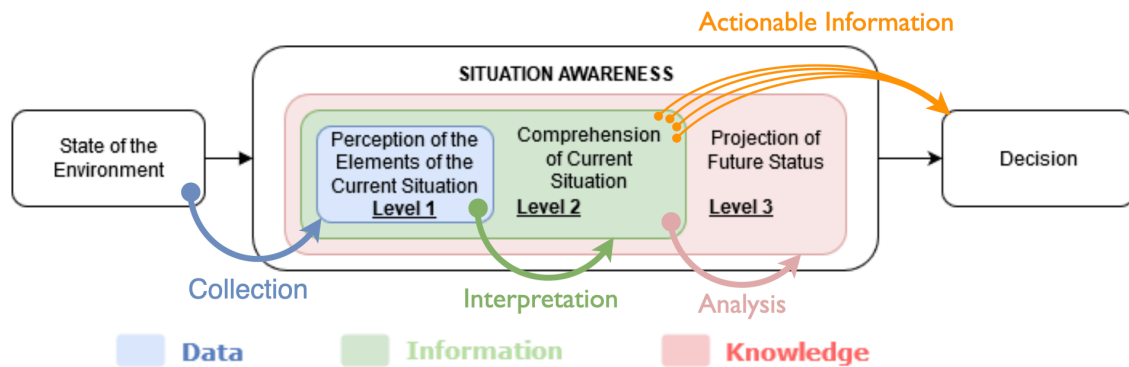
Figure 2. Location of Data-Information-Knowledge concepts in the Situational Awareness model

Situational Awareness is built upon any Data or Information about the current state of environment and that is delivered to the decision-maker. Using the previous proposition, we are now able to envision a relationship between Situational Awareness and Actionable Information. As Actionable Information is a type of Information, it is then embedded in the second level of Situational Awareness. The difference with regular Information, is that Actionable Information is the missing piece of the puzzle that allows the decision-makers to make a decision. As a result, Situational Awareness is the puzzle comprised of pieces of Information that decision makers try to assemble during the event, and Actionable Information constitutes the final, missing pieces of that puzzle necessary to comprehend the whole. Actionable Information is then a specific piece of Information in the Situational Awareness model. As mentioned in the literature review above, (Zade et al. 2018) identify five features that make an information actionable (role of the responder, timeliness, location, credibility and context). Here, we make the claim that responders' role, timeliness of the information, location and credibility are all impacted by the context (type, scale, location, responders' capabilities, and capacities among others). Moreover, Thus, we consider that actionable information is information that satisfies four criteria:

- Relevant: the information is delivered at the right place, to the right person.

- Timely: the information is delivered at the right time during the event.

- Precision: the information has to provide precise information. Location is the most requested precise information, but other such as the number of persons involved in an incident fits in this category.

- Reliable: the information is credible and can be verified.

All these criteria are context-dependent. As an example, when is an information delivered "at the right time"? The right time can be seen as a time window allowed by the acquisition of previous incomplete information, with missing parts and where a new incoming information to complete the puzzle. Therefore, there can be no one-size-fits-all social media processing system that provides only Actionable Information to the user. In (Silberschatz and Tuzhilin 1996) the authors describe two major issues with the processing of Actionable Information: (i) there are a lot of patterns of interest, that have to be divided into a finite set of action-pattern equivalence; (ii) pattern-action associations are likely to change overtime, thus, the life cycle of these associations has to be managed. The concept of actionable information is important, yet subjective and fuzzy, as the criteria above show. But while there could be no definitive definition, there is definitely room for improvement in the way that the information retrieved by social media processing system is organized.

IMPLICATIONS FOR SOCIAL MEDIA PROCESSING SYSTEM DESIGN

As (Zade et al. 2018) highlighted, proposed social media systems have not been widely adopted by emergency responders. Among all the reasons that could explain this lack of interest, some are certainly related to the design of the systems. Systems initially developed were focused on increasing the amount of information provided to first responders. However, the misfit of the categories used by these classification systems ultimately lead to adding noise in the processing. In addition, the information did not always fit the responder's need, resulting in additional noise. Current systems handle data collection and information extraction. But the resulting flow might still be overwhelming for social media operators. The systems developed should require a minimal amount of attention from the operators on the menial tasks, while keeping her engaged. As the goal of increasing the volume of information

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available to emergency managers can be considered as achieved, future work could concern information quality. This quality improvement can be achieved by adding support to Actionable Information identification. But, as stated earlier, Actionable Information can be identified by systems only by having a sufficient Situational Awareness at first hand. Thus, social media processing systems need to be able to both perceive and comprehend the situation.

Solidifying SA's Assets

Systems to improve SA were built throughout the decade. Significant lessons have been learn along the way. It might be beneficial to undertake a revision of the design principles that guided the first situational awareness systems in the light of this feedback. (Endsley 2016) offers some guiding principles, focus on the user, to the design of Situational Awareness support systems. As an example, the authors identify 8 "demons" (factors) that harm the Situational Awareness of the operators:

- Attentional tunneling: fixating one set of information to the exclusion of the others.

- Requisite memory trap: over reliance of the system on the operator's short memory.

- Workload, anxiety, fatigue, and other stressors

- Data overload

- Misplaced salience: misplaced warnings or sign that incorrectly catch the user attention

- Complexity creep: complex systems, cluttered of features, prevent the user to create an accurate mental model

- Errant mental models: incorrect mental models ultimately lead to poor comprehension and projection

- Out-of-the-loop syndrome: automated systems sometime do not completely inform the user

Moreover, in a later chapter, the authors provide thoughts on the automation of SA-related problems. Automation can be responsible of three issues: (i) out of the loop syndrome, (ii) inaccurate understanding of the system by the operator and (iii) diminishing return of decision support systems. To prevent theses caveats, the authors of this article advise for an adaptive automation and choose the right level of automation. They organize their recommendations through eleven principles:

- Automate only if necessary

- Use automation for assistance in carrying out routine actions rather than higher level cognitive tasks

- Provide SA support rather than decision

- Keep the operator in control and in the loop

- Avoid the proliferation of automation modes

- Make modes and system states salient

- Enforce automation consistency

- Avoid advanced queuing of tasks

- Avoid the use of information cueing

- Use methods of decision support that create human/system symbiosis

- Provide automation transparency

These insights are valuable in the design of an effective social media processing system for crisis response. Yet, these principles will only be valuable to provide a better SA to the user of such system.

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Environment Comprehension and Actionable Information identification

Once systems are able to correctly figure support the first level of Situational Awareness of its users, it is then possible to support the second level. The comprehension of the environment corresponds to the acquisition of Information from the Data acquired during the perception. Many of the social media processing systems mentioned in the Introduction section are already able to process Data to create some Information. Currently, few of them are capable to provide Actionable Information directly. To do so, the system must be capable of identifying Information that correspond to some criteria like those proposed by (Zade et al. 2018). However, being able to define an Information as Relevant or Timely require an understanding of the context of the Information. This context is created by managing and organizing the Information created from the Data. Integrating the Information acquired in a temporal and geographical framework allows subsequently to create relationships between these different pieces of Information. This will had a few extra segments compared to the previously used architecture. Generally, systems were composed of a layer for data collection and management, and a layer for information creation. For instance, a new system's architecture could instead be composed of four segments:

1. Data collection and management

2. Information creation (to support level 1 of Situational Awareness)

3. Information management (to support level 2 of Situational Awareness)

4. Information filtering (to identify Actionable Information)

Data collection and management, as well as Information creation already gained attention. However, Information Management and Information filtering to produce Actionable Information remains mostly unexplored. (Bidoux et al. 2019) explores automated planning to propose a strategy to handle the event in an efficient way. To do so, the authors propose a planning based on Multi Criteria Decision Analysis and make it specific to the event using a preference approach. There are, however, some systems that have already attempted to integrate actionability into their design. (Avvenuti et al. 2018) created CrisisMap. A social media processing system that aims at identifying some of the factors to provide a more actionable information to the operators. The system extracts potential crisis-related actionable information from tweets by adopting a classification technique based on a combination of readily-available semantic annotators to geo-parse tweets. However, while the article uses this term, it is unclear if the authors investigated its meaning or conflated it with situational Awareness. (Coche et al. 2021) also envisioned a system that would go a step further, by not processing the data, but the information extracted. This is achieved by encoding the appropriate categories through a metamodel of collaborative behaviors in a crisis environment. The system could be able to automatically infer relationships between the different classes of information extracted and identify by itself if the information is indeed actionable and then, worth mentioning to the user.

CONCLUSION

Crisis responders' needs are still largely unexplored, and work similar to those undertaken by (Kropczynski, Grace, et al. 2018; Zade et al. 2018) are the corner stone to the development of efficient and usable social media data processing systems. Many advances have been made to make it easier for crisis managers to process social media data. However, improving the situational awareness of decision makers proved to not be sufficient, we are still unsure about the fact that identifying actionable information is the missing part. In fact, there could be other alternatives to just the "right information". (Silberschatz and Tuzhilin 1996), along actionable information, use the "unexpectedness" of the information as another indicator. One could also argue that the low quality of the data on the social media prevents the discovery of actionable information. While this argument is interesting and has valid origins, we live the study of the impact of the data quality for future work.

In this article, the authors motivation is to further explore the initial problematic(s) of crisis informatic, to build systems that would better address responders needs. The literature review to cover the previous propositions of definitions for both concepts and their evolution. The third section presents a revision of Endsley's mode and argue that Situational Awareness and Actionability are part of the same picture. The last section use the outcomes of the two previous sections to provide insights for future system's design. Based on our review of literature on the topics of situational awareness and actionable information, we believe the combined model proposed in this paper may be useful to consider when developing data processing tools in the future. Future work should test this model with additional use cases, cognitive testings, and case studies for validation of the model. We contribute our work as an extension of the discussion on social media analysis tools for situational awareness and their application for gathering actionable information in the future.

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