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ORIGINAL RESEARCH

Enhancing Disease Surveillance Event Communication Among Jurisdictions

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Abstract: Automated disease surveillance systems are becoming widely used by the public health community. However, communication among non-collocated and widely dispersed users still needs improvement. A web-based software tool for enhancing user communications was completely integrated into an existing automated disease surveillance system and was tested during two simulated exercises and operational use involving multiple jurisdictions. Evaluation of this tool was conducted by user meetings, anonymous surveys, and web logs. Public health officials found this tool to be useful, and the tool has been modified further to incorporate features suggested by user responses. Features of the automated disease surveillance system, such as alerts and time series plots, can be specifically referenced by user comments. The user may also indicate the alert response being considered by adding a color indicator to their comment. The web-based event communication tool described in this article provides a common ground for collaboration and communication among public health officials at different locations.

Keywords: public health surveillance, communication, collaboration, world wide web, software, public health practice, bioterrorism

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Introduction

Automated disease surveillance systems provide public health officials with the ability to view large amounts of population health information and examine alerts generated by statistical algorithms that may suggest increased infectious disease activity.[1,2] These systems are designed to detect statistical anomalies across a variety of different types and large amounts of public health data,[3] such as hospital emergency department (ED) chief complaints, physician office visit International Classification of Diseases 9th Edition (ICD9) codes,[4] and over-the-counter drug sales. These data are typically sent to and ingested by the system as frequently as the data are made available, often on a daily basis. Public health officials then apply their expertise to interpret the statistical alerts to determine which, if any, are of epidemiological importance.[5] This expert interpretation is valuable information that may benefit other surveillance system users who are not in the same location. Public health officials also use these surveillance systems for situational awareness and as a common snapshot of disease levels with which to share their concerns and findings about disease activity before determining whether further investigation is warranted and/or a public health emergency should be declared. Once the public health department has determined that a significant public health event is occurring, these surveillance systems then enable the users to estimate the magnitude and location of the outbreak and determine the appropriate type of government response. Therefore, the ability to communicate these local public health concerns and findings during a health event to public health officials in different levels of government or in neighboring jurisdictions is of great public health importance because it enhances detection and allows for improved coordination to prevent further spread of the disease.[6–9]

Public health officials can communicate concerns and findings of disease surveillance systems with other public health officials in a variety of ways, including telephone calls; reports and spreadsheets sent via fax, mail, or email; electronic bulletin board systems (BBS); or electronic chat. Other authors have proposed using the World Wide Web as an infrastructure for cross-platform cooperative work among locally dispersed working groups and for use in multi-center clinical trials.[10,11] The Health Alert Network[12] and ProMed[13] are examples of web-based systems that allow public health officials to communicate findings to peers, but these systems focus more on events that have already been detected or confirmed. The need for effective electronic communication to enhance public health surveillance has long been recognized.[14] In this paper, we describe the Event Communications Component (ECC) module, an event communication tool that was integrated within the Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE), and the improvements made to this tool following its evaluation by users during two simulated disease outbreak exercises.

The integrated communication tool described in this paper has important benefits over other forms of communication. First, complete integration within the disease surveillance system allows direct linking to and sharing of alerts, and displays information that is the source of the user's concerns. This feature provides common grounding and explicit referencing, which has been shown to improve collaboration.[15] Because public health officials already use the disease surveillance system to review detection alerts and health information, a communication tool integrated into this system facilitates collaboration among those users who are not co-located, especially those in neighboring jurisdictions and other levels of government.[16] Secondly, the communication of user concerns may be used to augment existing functionality in the disease surveillance system. For example, an event communication tool may allow users to identify the specific detection alerts, types of data, and case definitions that users in other jurisdictions believe are worth further investigation and monitoring. By electronically archiving users' epidemiological concerns and interpretations over a period of time, such an event communication tool will create a "labeled" dataset. This "labeled" dataset retrospectively records when actual outbreaks of epidemiological significance occurred and whether those outbreaks were successfully found by the surveillance system's detection algorithms (Fig. 1). Examination of this historical "labeled" dataset may provide information that can be used by system designers to enhance the detection algorithms.

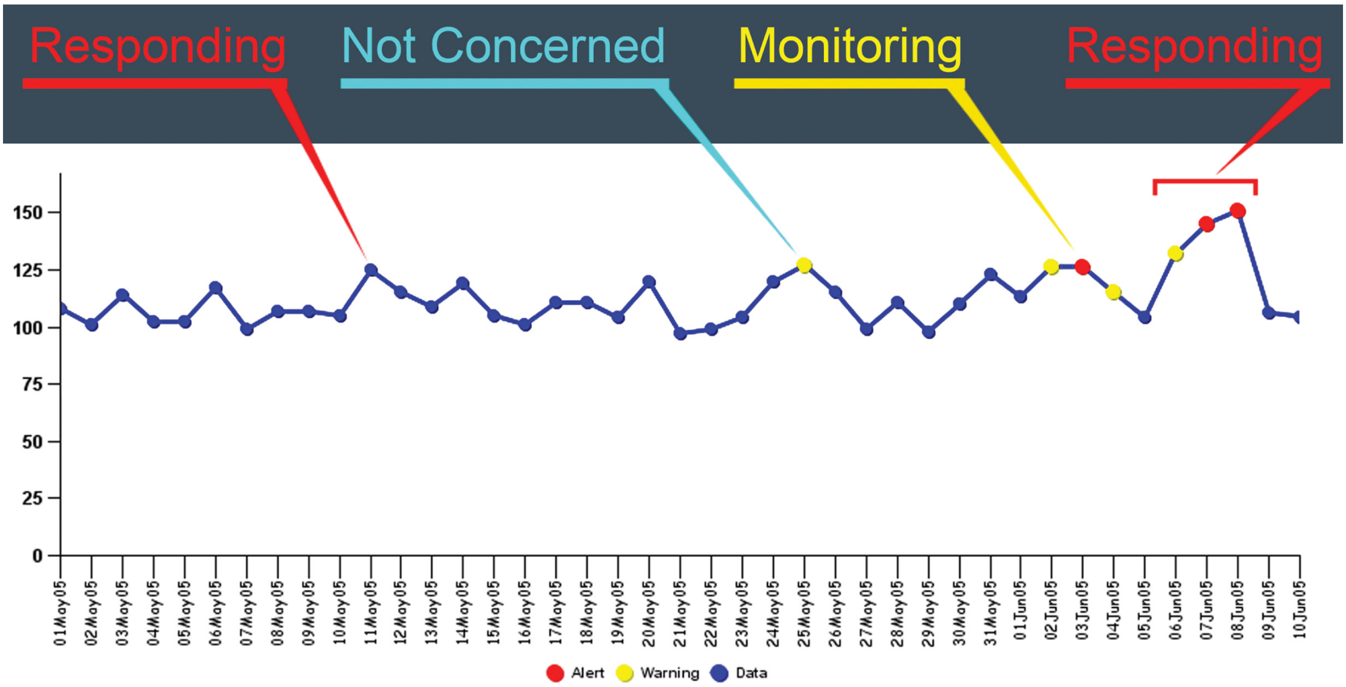

Figure 1. Time series depicting notional labeling of alerts in health data with a users' concern level.

The ECC was created to provide a common venue for sharing user concerns and interpretations of detection alerts and health data among different public health offices and jurisdictions who would not normally share their detailed health data without legal data sharing agreements. Therefore, the emphasis is on sharing information and interpretation rather than the more sensitive health data details. The ECC was developed as an integrated component of the ESSENCE system, a web-based disease surveillance system.[1] In 2004, The Johns Hopkins University Applied Physics Laboratory (JHU/APL) worked with public health officials in the National Capital Region (NCR) to establish the NCR syndromic surveillance network. The NCR consists of epidemiologists and public health officials from different local governments in the District of Columbia (DC) and surrounding Maryland and Virginia counties. The NCR syndromic surveillance network uses four instances of ESSENCE to create a network. For cross-jurisdictional sharing, data from each standalone system is de-identified, aggregated, and sent to a regional node where additional analysis is performed with results made available to all authorized public health personnel in the region. The NCR syndromic surveillance network provided an opportunity for JHU/APL to test the ECC for its ability to facilitate communication among different jurisdictions within the NCR.

ECC Description

The main user interface of the ECC is the Event List. A user creates an "event" (Fig. 2) in order to share information with or obtain additional information from other users in different locations. Therefore, a user-defined event may or may not turn out to be of epidemiological significance. These events consist of the following elements:

- A text block where the user describes the situation
- Structured meta-information such as location, age group, syndrome, and data sources affected
- The onset date and duration
- A status indicator that tells if the event is open or closed
- A "severity" rank that indicates the user's level of concern
- Read/unread status indication

The Event List (Fig. 3) displays the most recent events created by users. In the example, the small pane on the left shows the syndrome list. The larger pane

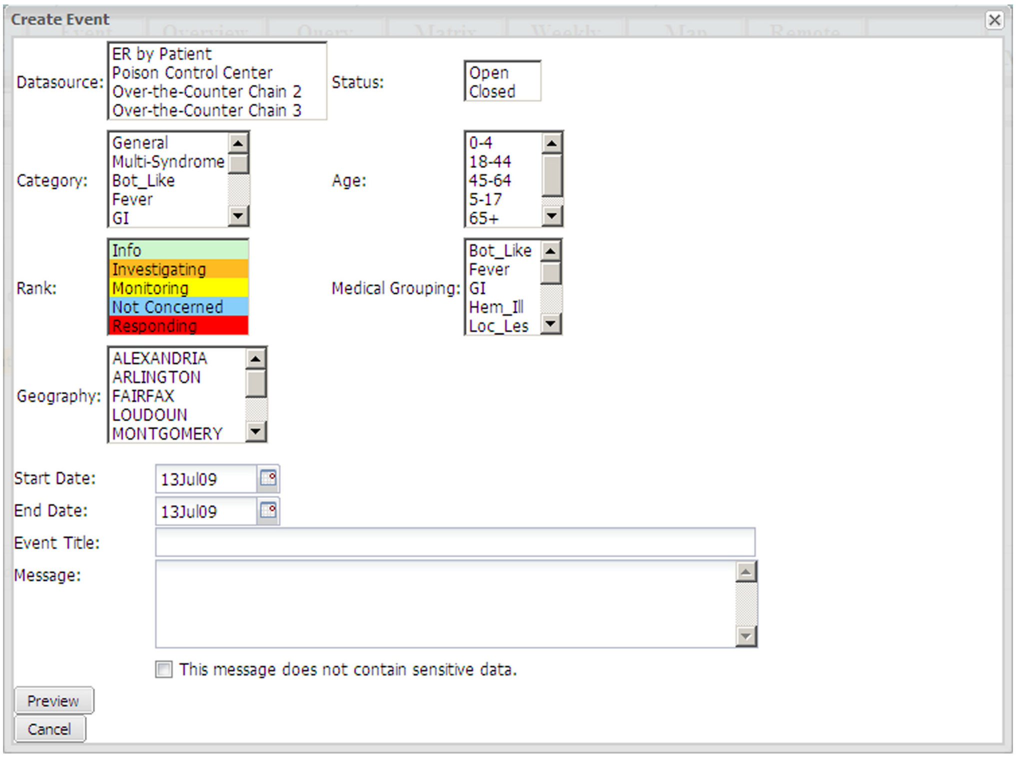

Figure 2. Web-based form used to create an "event."

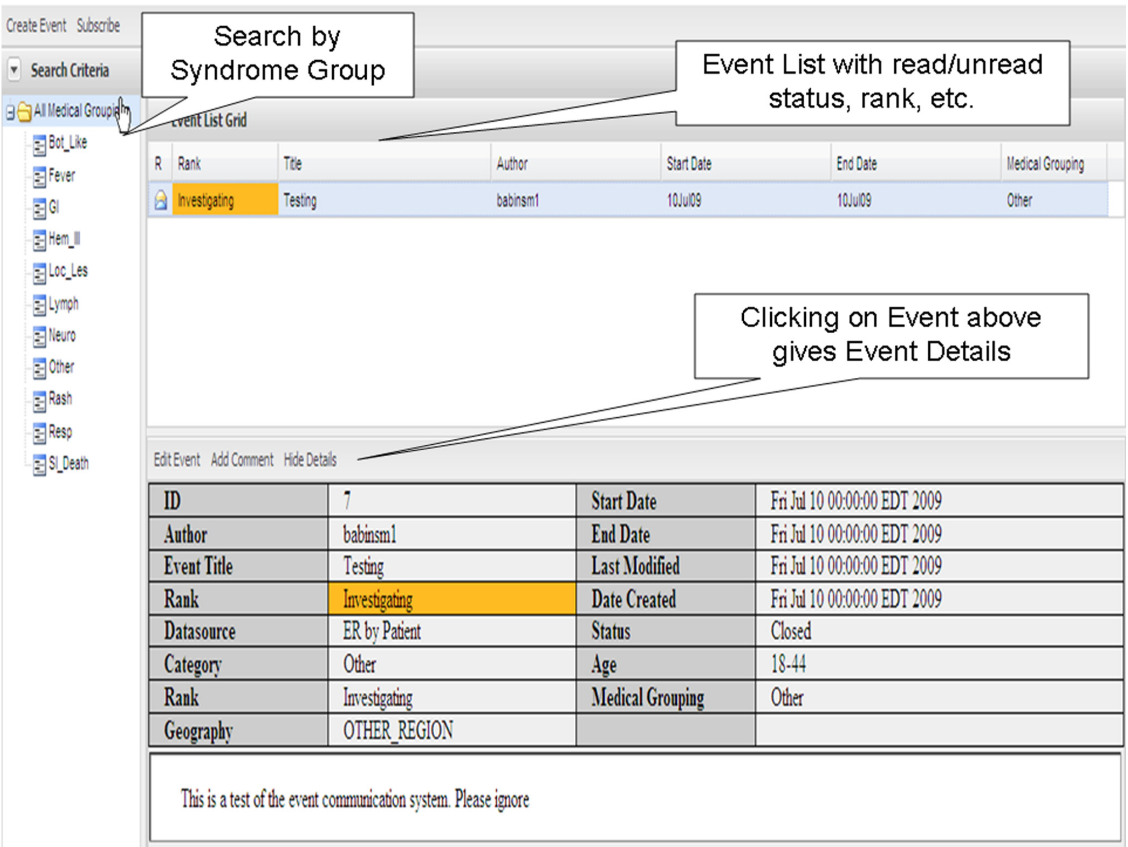

Figure 3. An event list showing an example of an event created by users.

at the top labeled "Event List Grid" contains the list of events created by users, where the column labeled "R" indicates the read/unread status for the user. The user-defined events are arranged in a sortable list in the center of the webpage. By clicking on an event, users can view its details in the lower pane. The Search Criteria button allows the user to search comments by user-specified criteria. The Reply feature enables other users to post their responses to these events and discuss their interpretations and findings, or share similar event information. In addition to entering text and meta-information regarding an event, users may also enter hyperlinks to other ESSENCE pages (e.g. time series plots, detection alert lists, or maps). This feature provides authorized readers with immediate access to view the health data or alerts being discussed.

In addition, the ECC meta-information is directly used to augment situational awareness via the Summary Alert List (Fig. 4). The Summary Alert List provides both statistical and epidemiologic information about potential disease threats to the community in a single view. The list is displayed as a table with each syndrome assigned to a column and each geographic region assigned to a row. Each syndrome/location cell in the table contains a row of stars

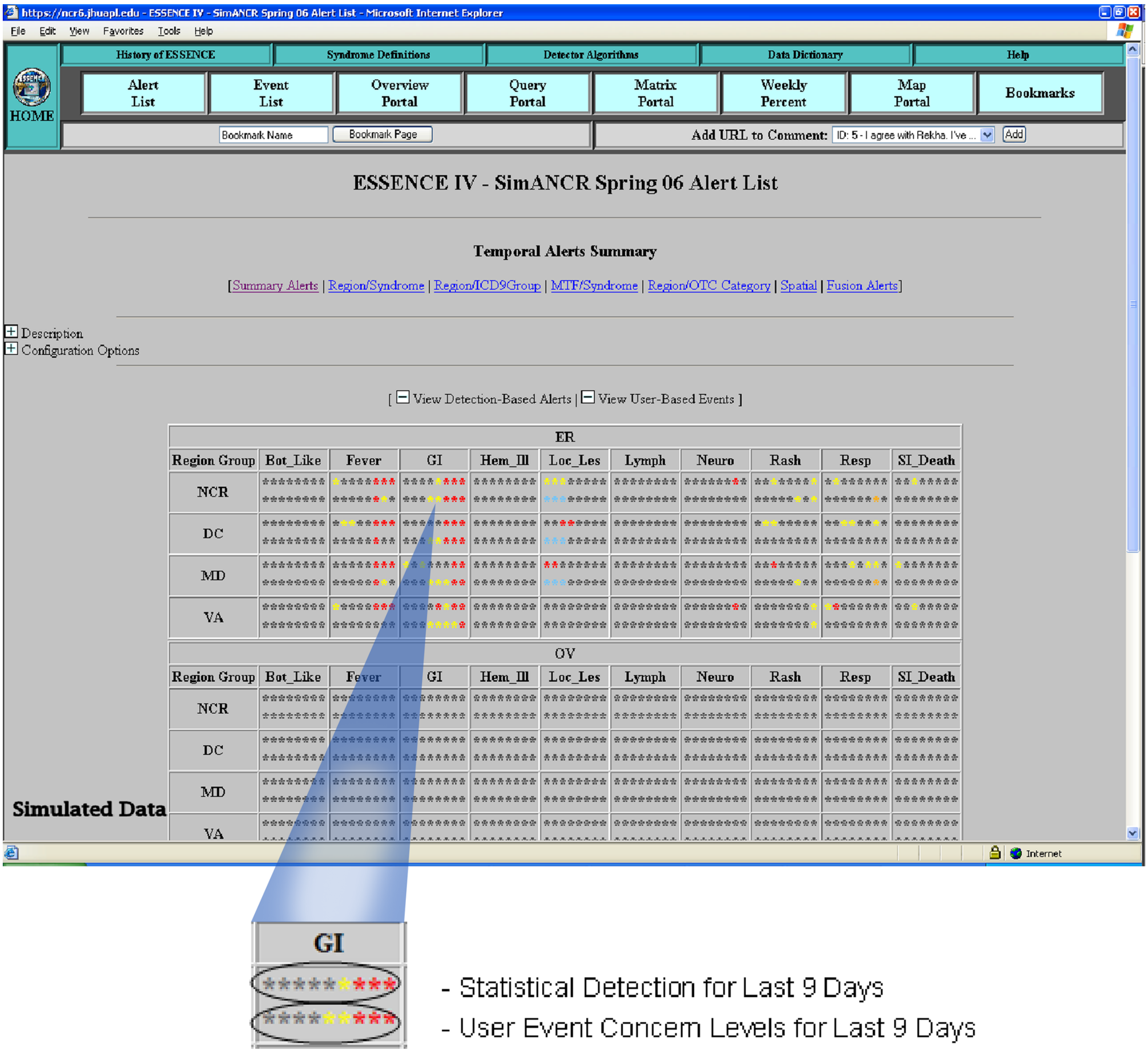

Figure 4. Summary alert list with both mathematical and user-created event alerts.

(see call-out in Fig. 4), where the color of each star represents the alert level for a specific day. The farthest star to the right in each cell represents the current day and the eight stars to the left represent the past eight days. The first row identifies the statistical detection for the last 9 days. When the detection algorithms identify a statistically significant increase in disease "activity" in a syndrome/location cell, the statistical alerting algorithm stars (first row) change from gray to yellow or red depending on the statistical significance level of the alert. Thus, the Summary Alert List gives a single page overview of the alert status of data streams by syndrome and location. The second row of stars in each cell in the table shows the user's level of concern (Fig. 2) about "events" occurring in specific syndromes and locations: red for responding, orange for investigating, yellow for monitoring, blue for "not concerned", and green for information only. The call-out in Figure 4 shows an enlargement of the gastrointestinal (GI) alerts for the emergency room (ER) data in the NCR. The top row of stars shows the last 4 days have alerted: 3 red alerts and 1 yellow alert. The bottom row of stars shows that the last 5 days user events have had 3 red concern levels and 2 yellow levels.

Methods

The ECC was developed for integration into ESSENCE, which is a Java-based web application used to perform disease surveillance in the NCR. The ECC has a Java servlet backend and uses a combination of HyperText Markup Language (HTML) and Javascript, where the Ext.js Javascript library is used to develop the user interface. The user interface is data-driven based on a database table that contains the data fields used by the interface. Based on the descriptions assigned to these fields, the ECC automatically displays the correct set of user interface form elements allowing for input and viewing of an event and its associated comments. The ECC module was added to ESSENCE by providing a button for the Event list on the ESSENCE header bar, and also by modifying the ESSENCE Summary Alert List page. Because every instance of ESSENCE uses the same codebase, once the ECC is integrated into the codebase, it is available at all locations using ESSENCE.

After the ECC was incorporated as a module in ESSENCE, public health officials in the NCR evaluated its usefulness and features by participating in two separate regional exercises. NCR ESSENCE users include epidemiologists and public health officials from different levels of government. Maryland, Virginia, and the District of Columbia have users at the state/district level. Montgomery and Prince George's counties in Maryland and Arlington, Alexandria, Fairfax, Loudoun, and Prince William counties in Virginia have users that review county level data. In addition, Virginia has users from the northern Virginia regional health office.

The first exercise was conducted on May 30 to June 2, 2006 and included three days of system use followed by a meeting to discuss conclusions and lessons learned during the exercise. The simulation scenario for this exercise was a food-borne hepatitis A outbreak that spanned the three jurisdictions and was spread by a catering service. Two hundred and sixty-seven simulated patient cases were injected on top of simulated background health data over a three-day period. On each day of the exercise, users were allowed one hour and thirty minutes to monitor simulated data in the ESSENCE system for the occurrence of a disease outbreak. Users worked from their own offices and were therefore not in the same location, allowing them to fully simulate their normal ESSENCE review. Users were asked to complete a survey at the end of each day. At the wrap-up meeting after the completion of the exercise, users were asked to summarize their experiences and present their findings to the entire group.

The second exercise occurred on October 3–6, 2006. Users, consisting of many of the same participants from the previous exercise, again worked from their separate offices over a three-day period with a summary meeting on the fourth day. In this exercise, the simulation scenario consisted of human cases of H5N1 influenza in the UK with one case arriving in the U.S. by airplane. The users had to find a small outbreak of H5N1 influenza in the NCR that was buried in a wave of "worried well" patients arriving at local emergency rooms. Thirty-six simulated cases of H5N1 influenza and 1,627 simulated cases of "worried well" were injected over three days onto a background dataset. Similar to the first exercise, users completed a survey at the end of each day.

During both of these exercises, surveys were collected from the participants. The first exercise survey asked questions about the overall utility and desirability of specific features of the ECC. In the second exercise survey, questions focused on determining how users communicated with each other during the simulated outbreak, whether via ECC or another means. We were also able to analyze the user-created events and their associated comments during the exercises. In addition, website usage logs recorded when and how pages of the ECC were viewed by each user. These logs were used to determine feature utilization of the ECC. After each of these two exercises, each individual jurisdiction's summary presentation was also recorded during the wrap-up meetings. These presentations gave insights into the utility of the ECC from each jurisdiction's perspective.

The ECC became operational in the NCR ayndromic surveillance network on May 1, 2006. Website usage logs and records of the created events and comments were available for the 10-month period of operational use. This information was used to determine further improvements to the ECC. During this operational period, usage logs showed that the Event List module was accessed nearly as often as the ESSENCE home page, or nearly every time a user logged on.

Results and Discussion

The ECC has been operational for over three years in the NCR syndromic surveillance network and has been tested during two simulated exercises described above. Observations, web usage logs, and user survey data from the first exercise provided the following findings from 21 total survey respondents:

- 11 (52%) participants reviewed event comments posted in the ECC before conducting their initial data review for this exercise
- 14 (67%) participants stated that they think the ECC serves a critically needed function
- 18 (86%) participants stated that the ECC is intuitively designed
- 18 (86%) participants stated that using the ECC is worthwhile and that they would use the ECC in practice
- 11 (52%) participants favored using ECC for communicating suspected events, outbreaks, and non-events (i.e. routine daily findings)
- 7 (33%) participants favored using ECC only for communicating suspected events or actual disease outbreaks
- 3 (14%) participants stated they were unsure.

Of the seven participants who favored using ECC only for suspected or actual outbreaks, three stated that a separate set of webpages would be valuable to communicate routine findings and/or daily observations.

The second simulation exercise was held with the survey questions more focused on how the participants communicated with one another rather than rating various features of the ECC. This survey had 22 respondents. The results of what was communicated and how it was communicated each day of the three-day exercise are shown in Table 1.

During a period of operational use following the two exercises, web usage logs and observations of ECC usage were maintained. During May 1, 2006 through March 15, 2007, web usage logs and observations showed that 54 user-defined events were created by eight different users in the NCR. These events had 98 comments by the same users and were distributed among all syndromic categories. In addition, the Event List was accessed nearly every time a user logged in and checked the disease surveillance system. Table 2 summarizes the view counts by system web page.

A possible criticism of the surveys is that they had a positive bias in the phrasing of questions. However, the overwhelming majority of participants stated that they would use the ECC in practice even when that positive bias was taken into account. Users were also asked about potential ECC enhancements that they would like to see and the priority of incorporating these features. Specifically these improvements

Table 1. Summary of survey results from the second simulation exercise.

Sent info to other public health jurisdictions	Day 1	Day 2	Day 3
Found anomalies	7/8	9/9	4/5
Contacted other public health agencies	7/7	9/9	5/5
Used ECC	6/7	9/9	4/5
Used email	1/7	8/9	3/5
Used phone	2/7	1/9	1/5
Used fax	0/7	1/9	1/5

Table 2. Website page view counts.

Web page	# Views
Event list	973
Home page	1219
Time series	3788
Data details	1972
Summary alert list	3279

concerned: the need for user-defined automated notification of new events/comments; the adoption of a comment-centric (as opposed to an event-centric) design; the visualization of read/unread status, and the use of action-oriented concern levels. The following sections review the above survey findings and describe the subsequent improvements and modifications made to the ECC.

Notification

One issue with the original version of ECC was the lack of *automatic* notification for new events/comments. At the suggestion of the system users, this notification mechanism was added allowing users to configure event criteria in order to receive electronic mail (email) notification (Fig. 5). These criteria include data source, category, rank, geography, status, age, and medical grouping. Real-time notification is also available in the form of floating message boxes that the user can see while viewing other system pages.

Comment-centric design

The first version of ECC used an event-centric design. Events were handled as separate threads of conversation and comments were only viewable if the users explicitly opened the event associated with those comments. The users felt that this design was too limiting. Also, this earlier design made users more likely to create new events than search for similar events and then comment on those similar events, thereby creating many separate events that were essentially about the same public health anomaly—thus inhibiting multi-user collaboration. To solve this problem, ECC version 2.0 incorporates a comment-centric design. Comments are displayed inline with their corresponding event. This allows users to view immediately all discussion related to an event (see Fig. 3). Also, similar events may be grouped together by the use of medical groupings and search filters. For example, users are able to view all respiratory syndrome-related events together. ECC 2.0 also provides the use of

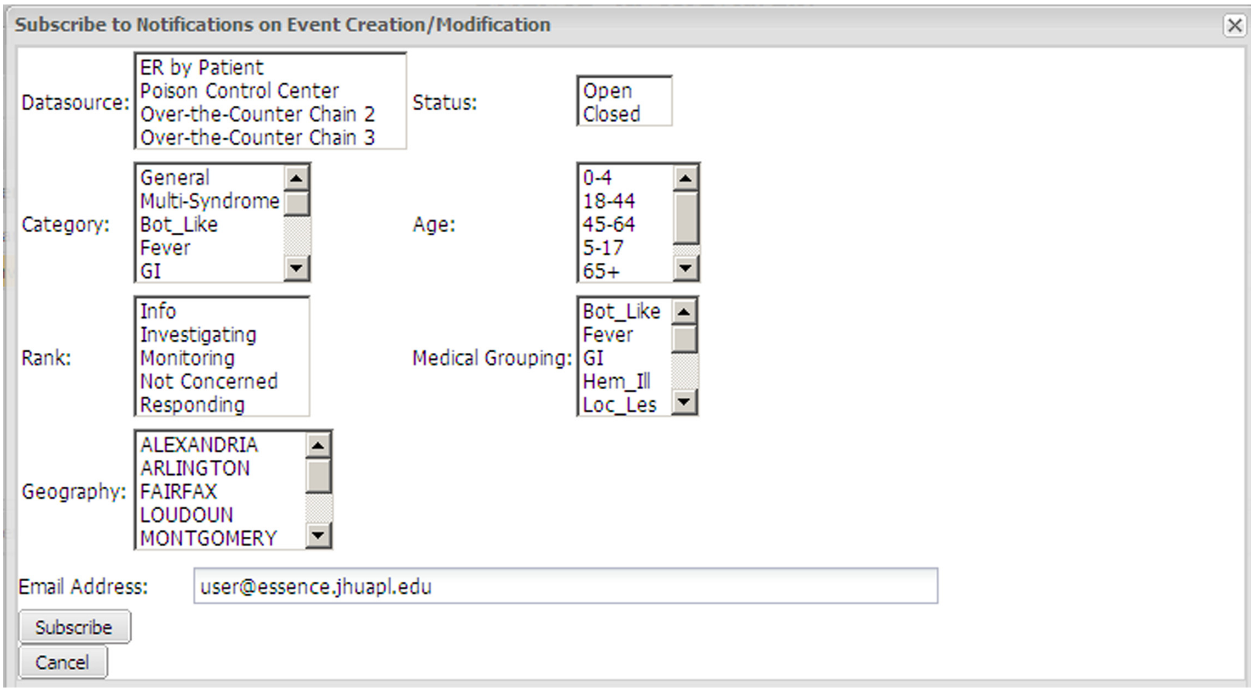

Figure 5. User configuration options that define the comments to be emailed.

tabbed panes that allow the viewing of multiple lists of events at the same time. Other improvements include an auto-refreshing event list, text searching, and the integration of a rich text editor.

Read/unread status

Users are able to determine which comments have been read or not read, and which ones have replies. Icons now display the read/unread status for each event (Fig. 3).

Action-oriented concern levels

Originally, the ECC had generic concern levels: "Info," "Low," "Guarded," "Elevated," and "High." Users felt these levels were ambiguous in their meaning. Instead of these generic levels, ECC 2.0 uses action-oriented ranks such as "Not Concerned," "Monitoring," "Investigating," and "Responding." There is also an "Info" rank for the user to share any relevant background information. While the user specifies one of these levels when creating the event, another individual examining the event may reply to it and add a different level of concern rank (Fig. 6).

The following example shows how the ECC can be used by public health officials to monitor the population-based health data within and across neighboring jurisdictions. Public health user A in jurisdiction A is investigating an increase in fever syndrome within their jurisdiction. After examining the results of the disease surveillance system, they decide that the situation is worth monitoring and that they should communicate their concerns to neighboring jurisdictions. Therefore, user A creates a new Event in the ECC by completing the web-based form to describe the situation from their perspective. Using the ECC, they select the syndrome (Fever), location (jurisdiction A), and the datasources they are monitoring. They add other demographic information about the population that seems to be involved. They select the "Monitoring" rank and give their event a free text Title and Description. In addition, they attach either a URL or a saved screen shot image so other users can see the time series of the data of concern. Once the user posts the event, users in other jurisdictions can view, search, and comment on this event. When a user views the ESSENCE Summary Alert List, they will also see a star with the color indicating the rank of the concern. Other system users are now alerted to a potential increase in Fever syndrome and can begin investigating their own jurisdictions and respond to the event by creating their own comments based on their perspectives. In this way, all users may determine whether the event is significant and whether it impacts their jurisdictions.

Conclusions

With the ability to monitor vast amounts of a wide variety of population-based health data, public health officials need the ability to communicate information about the health of their populations with other public health investigators both within and across multiple jurisdictions. This ability to share rapidly the concerns and interpretations of population-based health data with non-collocated peers both within

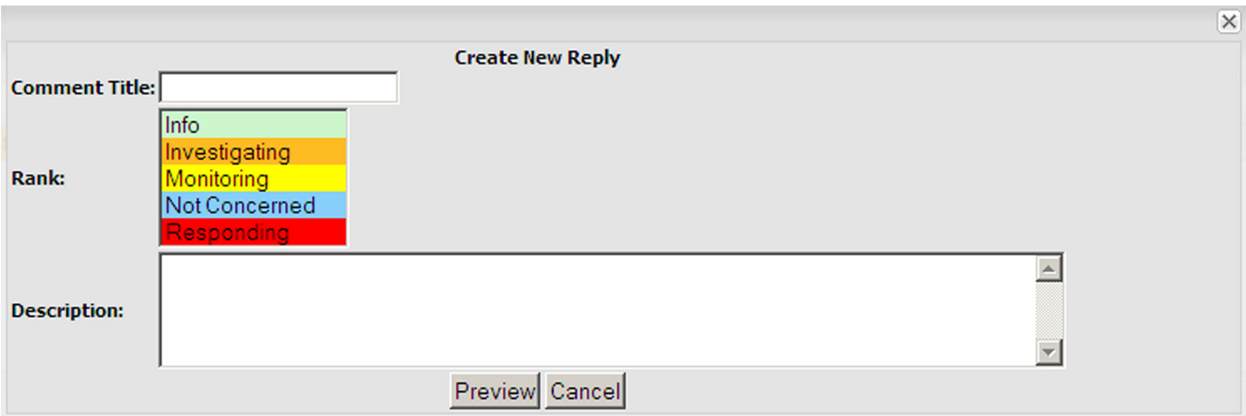

Figure 6. Action-oriented (information only, not concerned, monitoring, investigating, and responding) ranks allow users to rank their evaluation of the event.

and outside the public health user's jurisdiction facilitates timely communication of important health findings, situational awareness, regional collaboration, and improved public health response to disease outbreaks.

The ECC was evaluated by public health users during two simulated exercises and modifications were made to address their concerns and suggestions. Even before these modifications were made, the majority of users found the ECC worthwhile. The ECC functions similarly to a structured chat or message board, but with significant enhancements. First, it is comment-centric to provide the users with a means for avoiding phantom adjacency pairs where adjacent messages might not be related to one another. Second, it provides the means for explicit referencing by including the ability to incorporate webpage addresses into the comments. Such explicit referencing has been shown to significantly improve collaborative learning.[15] Finally, because the users are able to view the same information and provide mutual feedback on shared knowledge, the ECC fulfils the role of providing a common ground for the multi-government jurisdictional collaboration and communications that are required for effective detection and control of disease outbreaks. While there are versions of contextual chat that allow for integrated conversations within documents,[17] the ECC is integrated into a dynamically operating disease surveillance system in which detection algorithm results are always being updated as data (both new and old back-filled) are ingested. This type of integration means that the ECC does not depend upon having sticky chats tagged to specific documents that are later overtaken by new results. Therefore, such integration allows the ECC to mitigate the problem of having comments tagged to earlier webpage versions being lost, misleading, or irrelevant. In the ECC, public health professionals use a common Event List to communicate specific questions and share comments related to health information as the information related to an event evolves. While current versions of the ECC are specifically designed to work with the ESSENCE syndromic surveillance system, the above concepts have been used to design similar systems for other types of syndromic surveillance systems.

Competing Interests

The authors declare that they have no competing interests.

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References

1. Lombardo JS, Burkom HS, Elbert Y, et al. A systems overview of the Electronic Surveillance System for the Early Notification of Community-based Epidemics (ESSENCE II). *J Urban Health*. 2003;80(2)Suppl 1:i32–42.
2. Bravata DM, McDonald KM, Smith WM, et al. Systematic review: surveillance systems for early detection of bioterrorism-related diseases. *Ann Intern Med*. 2004;140:910–22.
3. Buckeridge DL. Outbreak detection through automated surveillance: a review of the determinants of detection. *J Biomed Informatics*. 2007;40:370–9.
4. Hart AC, Hopkins CA, eds. 2003 ICD9CM Expert for Hospitals Sixth edition, Salt Lake City, UT: St. Anthony Publishing, 2003.
5. Sokolow LZ, Grady N, Rolka H, et al. Practice and experience deciphering data anomalies in BioSense. *Morb Mortal Wkly Rep*. 2005 Aug 26;54(Suppl):133–9.
6. Naylor CD, Chantler C, Griffiths S. Learning from SARS in Hong Kong and Toronto. *JAMA*. 2004;291:2483–7.
7. MacLehose L, Brand H, Camaroni I, et al. Communicable disease outbreaks involving more than one country: Systems approach to evaluating the response. *BMJ*. 2001;323:861–3.
8. Bradley CA, Rolka H, Walker D, Loonsk J. BioSense: Implementation of a national early event detection and situational awareness system. *Morb Mortal Wkly Rep*. 2005;54(Suppl):11–9.
9. Perkins BA, Popovic T, Yeskey K. Public health in the time of bioterrorism. *Emerg Infect Dis*. 2002;8(10):1015–8.
10. Appelt W. WWW based collaboration with the BSCW system. In: SOFSEM'99, LNCS 1725. Edited by Pavelka J, Tel G, Bartosek M. 1999:66–78.

11. Wisniewski SR, Eng H, Meloro L, et al. Web-based communications and management of a multi-center clinical trial: the Sequenced Treatment Alternatives to Relieve Depression (STAR*D) project. *Clin Trials*. 2004;1:387–98.
12. McNabb SJN, Koo D, Pinner R, Seligman J. Informatics and public health at CDC. *Morb Mortal Wkly Rep*. 2006 Dec 22;55(Suppl):25–8.
13. Madoff LC. ProMED-mail: an early warning system for emerging diseases. *Clin Infect Dis*. 2004 Jul 15;39(2):227–32.
14. Vacalis TD, Bartlett CLR, Shapiro CG. Electronic communication and the future of international public health surveillance. *Emerg Infect Dis*. 1995;1(1):34–5.
15. Muhlpfordt M, Wessner M. Explicit referencing in chat supports collaborative learning. Proceedings of the 2005 Conference on Computer Support for Collaborative Learning, Taipei, Taiwan. International Society of the Learning Sciences. 2005:460–9.
16. Hauenstein L, Wojcik R, Loschen W, Ashar R, Sniegoski C, Tabernero N. Putting it together: The biosurveillance information system. In: Disease Surveillance: A Public Health Informatics Approach. Edited by Lombardo J, Buckeridge D, Wiley & Sons. 2007:240–2.
17. Churchill EF, Trevor J, Bly S, Nelson L, Cubranic D. Anchored conversations: Chatting in the context of a document. *CHI Letters*. 2000;2(1):454–61.