# Towards Public Health Dashboard Design Guidelines

Bettina Lechner and Ann Fruhling

School of Interdisciplinary Informatics, University of Nebraska at Omaha,
Omaha NE 68182, USA
{blechner,afruhling}@unomaha.edu

**Abstract.** Ongoing surveillance of disease outbreaks is important for public health officials, who to need consult with laboratory technicians in identifying specimen and coordinate care for affected populations. One way for public health officials to monitor possible outbreaks is through digital dashboards of summarized public health data. This study examines best practices for designing public health dashboards and proposes an optimized interface for an emergency response system for state public health laboratories. The practical nature of this research shows how general dashboard guidelines can be used to design a specialized dashboard for a public health emergency response information system. Through our analysis and design process, we identified two new guidelines for consideration.

**Keywords:** Medical information system, dashboard interface design, disease surveillance, public health.

## 1 Introduction

Public health crises such as the recent *Listeria* outbreaks or the 2009 influenza pandemic require the immediate attention of public health directors and practitioners who coordinate diagnosis and care for affected populations. Continual monitoring of the public health environment allows for faster response and may reduce the impact of such emergencies. To address this need, digital dashboards have been shown to be an effective means to quickly assess and communicate the situation. Often these dashboards include computerized interactive tools that are typically used by managers to visually ascertain the status of their organization (in this case, the public health environment) via key performance indicators (Cheng et al., 2011). Dashboards allow users to monitor one or more systems at a glance by integrating them and summarizing key metrics in real time to support decision making (Kintz, 2012; Morgan et al., 2008). In the medical field, dashboards continue to expand and have been used for purposes such as emergency response coordination (Schooley et al., 2011), patient monitoring (Gao et al., 2006), and influenza surveillance (Cheng et al., 2011).

The US states of Nebraska, Kansas, and Oklahoma use a public health emergency response information system (PHERIS) to allow hospital microbiology laboratorians to monitor and report public health episodes across their state. In the case of a potential outbreak the PHERIS is the tool used by the microbiologists at the clinical

F.F.-H. Nah (Ed.): HCIB/HCII 2014, LNCS 8527, pp. 49–59, 2014.

laboratory to consult with epidemiology experts at the State Public Health Laboratory through a secure connection over the Internet. This system provides functionality to send informational text and images of specimens between laboratories and the state public health laboratory. However, to further enhance the functionality and usability of the PHERIS it would be ideal if there were a single display screen (e.g. digital dashboard) where the State Public Health Director could immediately assess if there are any potential outbreaks on the cusp of happening with just a glance.

The first aim of our study is to analyze and apply dashboard specific design guidelines we identified in our literature review through a new dashboard interface optimized for real-time disease outbreak and public health emergency surveillance. Second, we will evaluate if there are any missing guidelines.

In the remainder of this paper, we begin by presenting background information on the public health area, on the PHERIS (the system that is used in this study), and on the various dashboard design guidelines found in the literature. Next, we present our application of the selected medical dashboard guidelines to the new dashboard design. Then we present our analysis of missing dashboard guidelines. We conclude with remarks on the next phases planned for this study.

## 2 Background

### 2.1 Public Health

Public health is defined as "all organized measures (whether public or private) to prevent disease, promote health, and prolong life among the population as a whole" (WHO, 2014). The mission of public health is "fulfilling society's interest in assuring conditions in which people can be healthy" (IOM, 1988).

Some of the goals of public health are to prevent epidemics and the spread of disease, protect against environmental hazards, promote and encourage healthy behaviors, respond to disasters and assist communities in recovery, and to assure the quality and accessibility of health services (Turnock, 2009). One of the essential services provided by public health agencies is to monitor the health status and to identify community health problems (Turnock, 2009).

In the USA, the Centers for Disease Control and Prevention (CDC) is the nation's leading public health agency, and is responsible for responding to health threats such as naturally occurring contagious disease outbreaks or deliberate attacks (CDC, 2011). To be able to fulfill this monitoring role, every time a suspected select agent (such as *Bacillus anthracis* ["anthrax"]) is encountered by a state public health organization, it needs to be reported to the CDC. To fulfill this requirement, the state public health laboratories of Nebraska, Kansas, and Oklahoma use a system which allows them to communicate with laboratories in their state electronically and collect photos and metadata of suspected select agents to report to the CDC.

### 2.2 Public Health Emergency Response Information System

The intent of the PHERIS (STATPack™) system used in this study was to address critical health communication and biosecurity needs in State Public Health Laboratory rural states. The Secure Telecommunications Application Terminal Package (STATPack™) system is a secure, patient-privacy compliant, web-based network system that supports video telemedicine and connectivity among clinical health laboratories. The overarching goal of this public health emergency response system is to establish an electronic infrastructure, largely using web technology, to allow secure communication among state public health hub and spoke laboratory networks in emergency situations.

Specifically, the STATPack™ concept involves taking macroscopic (gross) as well as microscopic digital images of culture samples and sending them electronically for consultation with experts at state public health laboratories. STATPack™ enables microbiology laboratories around the state to send pictures of suspicious organisms to the state public health laboratory, instead of the samples themselves, thus lessening the risk of spreading infectious diseases. The system includes an alert system that is bi-directional and has various levels of priorities (emergency, urgent, routine, and exercise).

STATPack™ is especially useful in states where much of the expertise is located in a hub laboratory, while most triage and decision making regarding specimen processing takes place in smaller spoke hospital laboratories. For some of the spoke laboratories, it is difficult if not impossible for them to describe to experts what they see in a culture sample. STATPack™ allows experts to actually see the sample immediately and assist with the diagnosis in a matter of minutes, eliminating the risks and time delay of shipping the sample by courier.

In the case of an emergency, an expert scientist at a hub laboratory can in real-time, remotely focus the camera on a suspicious organism, analyze the image, and respond to the spoke laboratory. If the organism is deemed a public health threat, the STATPack™ system can be used to send an alert to every laboratory in the network. Prior to STATPack™, the only option was to physically send the sample to the hub laboratory, which could take several hours or even a full day to receive.

State public health experts spend significant time monitoring public health threats such as influenza outbreaks. Monitoring multiple public health laboratories state-wide at a glance is often challenging due to having to search multiple places for information, data overload, continuous changes of statuses, not knowing what information has changed, and a need to evaluate the potential impact. To address some these challenges, we designed a dashboard that would present all the relevant information for a state-wide surveillance system on one screen. We will refer to this new dashboard as STATDash.

### 2.3 Dashboard Design Guidelines

In this section we present a meta review of existing dashboard design best practices and related guidelines. This includes several studies reporting on the development of different kinds of medical dashboards, ranging from influenza surveillance, patient triage monitoring, to radiology reporting. A list of studies is presented in Table 1. Most of these studies also included guidelines for *medical* dashboard design, not just dashboards in general. The number of guidelines featured in each study is shown in Table 1.

**Table 1.** Selected relevant research

| *Study* | *Subject* | *# Guidelines* |
|---|---|---|
| Cheng et al., 2011 * | Influenza surveillance dashboard | 5 |
| Dolan et al., 2013 | Treatment decision dashboard | 0 |
| Few, 2006 | Information dashboard design | 12 |
| Fruhling, 2004 | Public health emergency response system | 3 |
| Gao et al., 2006 | Patient triage monitoring for emergency response | 15 |
| Morgan et al., 2008 | Radiology report backlog monitoring dashboard | 4 |
| Schooley et al., 2011 | Emergency medical response coordination | 6 |
| Tufte, 2001 | Information visualization | 1 |
| Turoff et al., 2004 | Medical response information system | 8 |
| Zhan et al., 2005 * | Disease surveillance and environmental health | 4 |

As shown in **Error! Reference source not found.**, the number of guidelines specific to public health monitoring dashboards is relatively low -- only two studies providing a total of nine guidelines fall into this field (highlighted with an asterisk). When we widen the criteria to include all medical dashboard guidelines, four more studies presenting 33 guidelines can be included. Furthermore, there are two relevant papers discussing 11 best practices for medical/public health emergency response systems design. Also, two studies in the field of information visualization and general dashboard design have some overlapping relevancy and thus, are included.

The dashboard and data visualization guidelines developed by Few (2006) and Tufte (2001) were reviewed and considered in this study. Even though they are general in nature and not specific to medical dashboards we included them, because they provide important contributions to information visualization and dashboard user interface design.

We also included Turoff et al. (2004)'s eight design principles for emergency response information systems (not necessarily dashboards) in our literature review. We decided to do this because Turoff's principles are concerned with the content required to make emergency response information systems useful.

After identifying the most salient studies, we performed a meta-analysis of all the guidelines for dashboard design. In total, 58 guidelines were identified in the literature. Among these there were several recurring themes as well as guidelines unique to the medical field.

The most common themes were those of designing dashboards as customizable, actionable "launch pads", supporting correct data interpretation, and aggregating and summarizing information. Also frequently mentioned were adherence to conventions, minimalist design, in-line guidance and user training, workload reduction, and using GIS interfaces. 33 of the guidelines were unique to the field of medical dashboards, while 17 were not applicable and 7 were too general.

The other 50 guidelines can be sorted into these eight themes that emerged from their review. **Error! Reference source not found.** shows the number of guidelines in each thematic area and the studies represented within.

**Table 2.** Categorized guidelines

| *Theme* | *# Guidelines* | *Studies* |
|---|---|---|
| Customizable, actionable "launch pad" | 10 | Cheng et al., 2011; Few, 2006; Gao et al., 2006; Morgan et al., 2008; Schooley et al., 2011; Zhan et al., 2005 |
| Support correct data interpretation | 8 | Few, 2006; Gao et al., 2006; Morgan et al., 2008 |
| Information aggregation | 7 | Cheng et al., 2011; Few, 2006; Gao et al., 2006; Morgan et al., 2008 |
| Adherence to conventions | 6 | Few 2006; Gao et al., 2006; Schooley et al, 2011 |
| Minimalist aesthetics | 6 | Few, 2006; Gao et al., 2006; Tufte, 2001 |
| In-line guidance and training | 4 | Few, 2006; Gao et al., 2006; Zhan et al., 2005 |
| User workload reduction | 3 | Gao et al., 2006; Schooley et al., 2011 |
| GIS interface | 3 | Schooley et al., 2006; Zhan et al., 2005 |

Designing dashboards as customizable, actionable "launch pads" is the guideline that was mentioned most often. This theme is concerned with allowing users to drill down into different aspects of the dashboard and initiate actions based on the data presented to them. A sample best practice of this theme would be "Design for use as a launch pad" (Few, 2006).

The second most common theme is "support correct data interpretation", which is related to helping the user understand information and perform actions correctly. An example of a best practice would be "Support meaningful comparisons. Discourage meaningless comparisons" (Few, 2006).

Third, the "information aggregation" theme places an emphasis on condensing data to show only a high-level view of the indicators most important to the users. A sample of this theme is "Based on the back-end algorithm, the level and trend of the overall influenza activity are shown in the top left" (Cheng et al., 2011).

Further, the influenza monitoring dashboard in Cheng et al., 2011's study synthesizes five different data types/sources to provide an overview of disease activity from multiple perspectives. It provides drill-down functionality for each individual data stream, a one-sentence summary of the level and trend of influenza activity, and general recommendations to decrease the flu risk.

Similarly, STATDash provides several different data streams that allow for activity monitoring: They are Alerts sent to clients, Alerts received from clients, Images stored by clients, and the Network stability statuses.

## 3 Applying the Guidelines

We designed a dashboard interface for STATPack™ (STATDash) based on the guidelines we selected in our meta-review discussed above and also we used our own knowledge and expertise where there were gaps (Fruhling, 2006; Lechner et al., 2013; Read et al., 2009). Figures 1 and 2 show the same STATDash, but at different states. **Error! Reference source not found.** shows the overview screen, while **Error! Reference source not found.** shows the location drill-down screen.

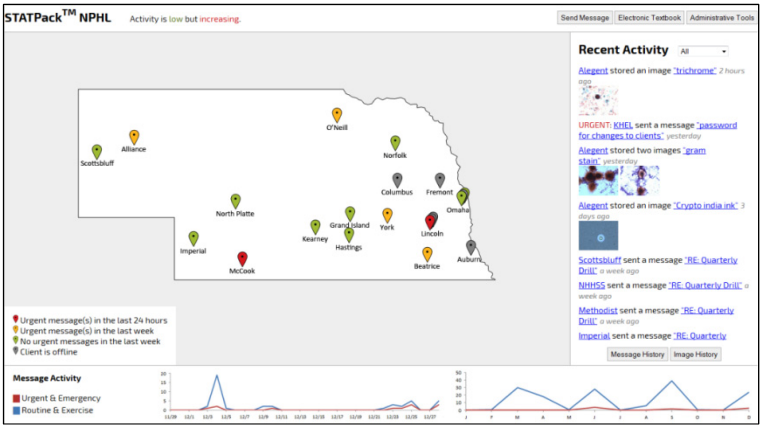


**Fig. 1.** Dashboard overview screen

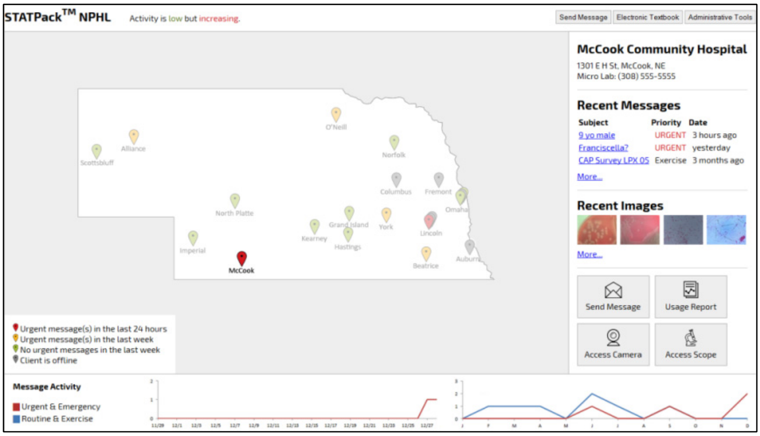


**Fig. 2.** Location drill-down screen

A discussion on how the selected guidelines were operationalized is presented in the next sections. We begin with the customizable, actionable, "launch pad" guideline.

## 3.1 Customizable, Actionable "Launch Pad"

The customizable, actionable "launch pad" guidelines (Cheng et al., 2011; Zhan et al., 2005) were implemented by having all surveillance data required by the state public health laboratory experts displayed on a single screen. This was achieved by showing the status of each location with a color code on a map. We also included two charts below the map that show the history of alert activity at various intervals: yearly, monthly or daily.

Activity is organized by routine/exercise and emergency/urgent alerts to allow the user to determine if a state of urgency exists. The right side of the screen shows details of recent activity (recent alerts received, clients becoming unavailable, and images stored). This list can be filtered to show only activity of a certain type. In addition, users can customize the thresholds used to determine the color a location is displayed in.

The dashboard is also actionable (Few, 2006; Morgan et al., 2008). Clicking on a location marker allows the user to view details about that location, such as recent alerts and images, contact information, and access to advanced functionality. In addition, clicking on a point in one of the charts shows the details of that data point.

These dashboard features require few touches/clicks to navigate the system (Schooley et al., 2011). When a user wanted to send an alert to a client in the old user interface, they had to click on the "Send Message" button, then locate the name of the client in a long list, select it, and then type their message.

### 3.2 Supporting Correct Data Interpretation

As discussed earlier, in the context of dashboard design, this guideline focuses on users correctly and accurately interpreting the data. It also includes that the data is analyzed correctly by the developers and displayed accordingly. By following this guideline, user errors can be reduced (Few, 2006). In our dashboard design, this is instantiated by allowing the user to compare current activity level charts to average activity over the life of the system for the respective time period. Since some disease activity can be seasonal, this allows the specialists to make direct comparisons to historical data.

### 3.3 Information Aggregation

As mentioned above, aggregated information is data that has been gathered and expressed in a summary form, often for the purposes of statistical analysis. In our example, the STATDash shows information aggregated at different levels. At the top of the screen, a statement informs the user about the overall level and trend of activity. The map allows a user to see activity by location at a glance by implementing a traffic light metaphor and different colors to convey meaning (Cheng et al., 2011; Morgan et al., 2008). The section on the right hand side shows more detailed, actionable information about the most recent -- most urgent -- activity. Finally, the two charts at the bottom give a summary of historical data. These four elements give a non-redundant, condensed, complete picture of disease activity following the guidelines presented by Few (2006) and Gao et al. (2006).

### 3.4 Adherence to Convention

Adherence to convention can be thought of as systems adhering to the same look and feel across the entire user interface and using familiar, established user interface elements. Convention was observed by retaining the same principles for core functionality as before, including alert meta-data and transmission. The terminology and labels within the system have also remained the same. Familiar symbols such as the map markers and traffic light color coding were employed. As such, it will be easy for users to learn to use the new dashboard, as they will already be accustomed to the functionality and terminology (Gao et al., 2006).

### 3.5 Minimalist Aesthetics

The design of the dashboard follows a minimalist aesthetic approach by reducing non-data "ink" that does not convey information (such as graphics and "eye candy") (Few, 2006; Tufte, 2001). One example is the map, which has been reduced to only show the outline of the state on a gray background and the locations of the clients as labeled markers.

As a second measure, colors have been used conservatively (Few, 2006). Most of the interface is white, gray, or black. Colors are only used to convey information, such as using colored markers for clients to indicate their status, highlighting urgent/emergency alerts in red, and showing the data lines in the charts as blue (routine and exercise alerts) or red (urgent and emergency alerts).

Advanced functionality such as sending alerts to a specific client is hidden from the initial view of the dashboard, thus reducing clutter and complexity (Gao et al., 2006).

### 3.6 In-Line Guidance and Training

In-line guidance is provided by choosing easily understandable labels (Few, 2006) that are based on the previous design and already familiar to the users. In cases where this was not possible, labels were chosen with user feedback.

Visual feedback to the user's actions is also important (Gao et al., 2006). This is achieved through a variety of means, such as dimming the other location markers on the map when one location is selected.

### 3.7 User Workload Reduction

The dashboard by design is intended to reduce the user's workload both cognitively and physically. A lot of this is accomplished through minimalist design and information aggregation.

### 3.8 GIS Interface

The map in the center of the dashboard provides situational awareness of disease activity and trends. This graphical display is combined with the performance indicators above and below the map for a multi-faceted view of the current status (Schooley et al., 2011). The map allows users to pan and zoom and select clients to view detailed information and interact with them.

### 3.9 Content

Every alert and image stored within the system is identified by its source and location, time of occurrence, and status (emergency, urgent, routine, or exercise) (Fruhling, 2006; Turoff et al., 2004). This allows users to clearly determine the source and severity of an alert and respond to it accordingly in the case of an emergency.

Up-to-date information that is updated whenever a user loads a screen (Turoff et al., 2004) is of great importance in an emergency response medical system and fully implemented in STATDash, to ensure all users have the most current information available to them for decision making.

### 3.10 Guidelines

Of the guidelines reviewed for this study, there were two guidelines that were not as salient for PHERIS dashboards; rather they are just best overall practices. “Adherence to conventions” is certainly a useful heuristic for designing dashboards, but it is too general to be included in a set of best practices specific to PHERIS dashboards. In a similar vein, providing “in-line guidance and training” is also too general. This guideline is applicable not only to this specific kind of dashboard, but to all computer systems in general (Nielsen, 1993).

## 4 Proposed New Dashboard Design Guidelines

The guidelines we found in our literature search were helpful in many ways; however, we identified two gaps. Therefore, we are proposing the following new guidelines.

### 4.1 Minimize Cognitive Processing

This guideline seeks to reduce the users’ cognitive load by including all indicators on a single screen without a need for navigation. In addition, charts and graphs should be used where sensible to show trends visually and for quick interpretation.

### 4.2 Use Temporal Trend Analysis Techniques

Temporal relationships and comparisons are important in recognizing patterns, trends, and potential issues. Therefore, the dashboard should have temporal capabilities to show trends over time and in relationship to historical data. In addition, information should be presented in a priority order based on recentness, urgency, and impact.

## 5 Conclusion

In conclusion, our analysis found several of the guidelines cited in the literature to be appropriate and useful for public health surveillance dashboard design, yet, we also discovered there were missing guidelines. Therefore, we propose two new guidelines: minimize cognitive processing, and use of temporal trend analysis techniques. A limitation of this study is that we have not validated the two proposed guidelines nor have we conducted any user usability evaluation on our proposed STATDash design. Therefore, the next phase of our research is to involve users in conducting various usability evaluations on STATDash.

## References


1. Centers for Disease Control and Prevention: CDC responds to disease outbreaks 24/7 (2011), `http://www.cdc.gov/24-7/cdcfastfacts/diseaseresponse.html`
2. Cheng, C.K.Y., Ip, D.K.M., Cowling, B.J., Ho, L.M., Leug, G.M., Lau, E.H.Y.: Digital dashboard design using multiple data streams for disease surveillance with influenza surveillance as an example. Journal of Medical Internet Research 13, e85 (2011)
3. Diaper, D.: Task Analysis for Human-Computer Interaction. Ellis Horwood, Chichester (1989)
4. Dolan, J.G., Veazie, P.J., Russ, A.J.: Development and initial evaluation of a treatment decision dashboard. BMC Medical Informatics and Decision Making 13, 51 (2013)
5. Few, S.: Information Dashboard Design. O'Reilly, Sebastopol (2006)
6. Fruhling, A.: Examining the critical requirements, design approaches and evaluation methods for a public health emergency response system. Communications of the Association for Information Systems 18, 1 (2006)
7. Gao, T., Kim, M.I., White, D., Alm, A.M.: Iterative user-centered design of a next generation patient monitoring system for emergency medical response. In: AMIA Annual Symposium Proceedings, pp. 284–288 (2006)
8. Institute of Medicine: The Future of Public Health. National Academy Press (1988)
9. Kintz, M.: A semantic dashboard language for a process-oriented dashboard design methodology. In: Proceedings of the 2nd International Workshop on Model-Based Interactive Ubiquitous Systems, Copenhagen, Denmark (2012)
10. Lechner, B., Fruhling, A., Petter, S., Siy, H.: The chicken and the pig: User involvement in developing usability heuristics. In: Proceedings of the Nineteenth Americas Conference on Information Systems, Chicago, IL (2013)
11. Morgan, M.B., Brandstetter IV, B.F., Lionetti, D.M., Richardson, J.S., Chang, P.J.: The radiology digital dashboard: effects on report turnaround time. Journal of Digital Imaging 21, 50–58 (2008)
12. Nielsen, J.: Usability Engineering. Academic Press, San Diego (1993)
13. Read, A., Tarrell, A., Fruhling, A.: Exploring user preferences for dashboard menu design. In: Proceedings of the 42nd Hawaii International Conference on System Sciences, pp. 1–10 (2009)
14. Schmidt, K.: Functional analysis instrument. In: Schaefer, G., Hirschheim, R., Harper, M., Hansjee, R., Domke, M., Bjoern-Andersen, N. (eds.) Functional Analysis of Office Requirements: A Multiperspective Approach, pp. 261–289. Wiley, Chichester (1988)

15. Schooley, B., Hilton, N., Abed, Y., Lee, Y., Horan, T.: Process improvement and consumer-oriented design of an inter-organizational information system for emergency medical response. In: Proceedings of the 44th Hawaii International Conference on System Sciences, pp. 1–10 (2011)
16. Tufte, E.R.: The Visual Display of Quantitative Information, 2nd edn. Graphics Press, Cheshire (2001)
17. Turnock, B.J.: Public Health: What It Is and How It Works. Jones and Bartlett Publishers, Sudbury (2009)
18. Turoff, M., Chumer, M., Van de Walle, B., Yao, X.: The design of a dynamic emergency response management information system (DERMIS). Journal of Information Technology Theory and Application 5, 1–35 (2004)
19. World Health Organization: Public health (2014), `http://www.who.int/trade/glossary/story076/en/`
20. Zhan, B.F., Lu, Y., Giordano, A., Hanford, E.J.: Geographic information system (GIS) as a tool for disease surveillance and environmental health research. In: Proceedings of the 2005 International Conference on Services, Systems and Services Management, pp. 1465–1470 (2005)