# Improving Situation Awareness with an Interactive Event Timeline in Collaborative Tabletop Interfaces

Y.-L. Betty Chang[1,3], Stacey D. Scott[1,3], Mark Hancock[2,3]
[1]Systems Design Engineering, [2]Department of Management Sciences, [3]Games Institute
University of Waterloo, Waterloo, Ontario, Canada
{betty.chang|stacey.scott|mark.hancock}@uwaterloo.ca

## ABSTRACT
Digital tabletops are being proposed and designed for complex collocated activities with dynamically changing data, such as crisis and disaster management and maritime operation. Human operators in these domains need to maintain a high level of situation awareness to appropriately and quickly respond to critical changes. Even though automation can help manage complex tasks and update information, it may create confusion and negatively impact operators' situation awareness. This work aims to improve situation awareness in collocated environments on digital tabletop computers by using an interactive event timeline that enables exploration of historical automated events. A collaborative board game was used as a case study. In this note, we present the design of the interactive event timeline and the two main design factors, ownership of the timeline among multiple users and placement of awareness feedback. We then discuss the experimental design to investigate trade-offs between the different setups and conclude with preliminary observations and future work.

## Keywords
Digital tabletop; gaming; automation; situation awareness; interaction design; collaboration;

## 1. INTRODUCTION
There is growing interest in using digital tabletop computers to support collocated group activities involving complex, often dynamically changing, digital data. Tabletop interfaces have been proposed for crisis and disaster management [3,9], military simulation [1], and military and commercial maritime operations [2,11]. Human operators in these complex domains need to maintain a high level of awareness of changing system data to respond quickly, with appropriate strategies. However, when the changes being monitored by the human operators are driven by highly automated processes, their awareness of system state may be negatively affected and leave them "out of the loop" [4]. Thus, they may be unable to understand or respond appropriately to such system changes. As digital tabletop applications become more sophisticated, leveraging automation to manage complex data in many domains while keeping users in the loop will be important to support real-world activities in these environments.

This work aims to improve situation awareness of dynamically changing data, especially changes driven by automated processes in collaborative contexts by using graphical interactive event timelines. Our goal is to enable optimal strategy formation by supporting Endsley's [5] three levels of situation awareness: the perception of changes in the system state, the comprehension of changes, and the prediction of future states. The interruption recovery literature has explored techniques to rapidly improve someone's awareness of changes in system state upon returning from an interruption. Findings from this literature have shown that graphical interactive event timelines with replay capability can improve response time and accuracy [12,13]. In this project, we propose an interactive event timeline that enables exploration of historical game events to improve situation awareness. Specifically, we explore the use of interactive event timelines to improve situation awareness of automated state changes in the context of a collaborative digital tabletop board game, *Pandemic*[1]. The Pandemic game has been previously shown to elicit "out of the loop" player behavior in response to automated game state changes when in-game events are automated [14].

This note describes our interactive event timeline design, and an initial experiment to begin exploring potential design factors that we believe may impact the effectiveness of the timeline to support situation awareness in a group setting. This initial study focuses on two main factors: placement of the awareness feedback and timeline ownership (i.e., one shared timeline per group or one dedicated timeline for each player).

We first present the physical and digital version of the Pandemic board game (Figure 1). We then introduce the design of the interactive timeline, and then describe the ownership and feedback placement factors. Next, we describe the experimental design for our user study and some preliminary observations. Finally, we conclude with future work.

## 2. PANDEMIC: PHYSICAL & DIGITAL
Pandemic is a 3 to 4 player collaborative board game that requires intense discussion on strategies and resource management (Figure 1, left). The goal is to work together in a team to save the world from epidemics and outbreaks of diseases. Players win by curing all the diseases, and lose if they run out of time (not having enough cards to draw from) or if the game state is out of control (too many outbreaks or diseases). Players have to manage the

**Figure 1:** (Left) The physical Pandemic board game; and (Right) The digital Pandemic board game.

[1] The physical Pandemic board game was published by Z-Man Games, used with permission. The digital tabletop game was implemented by the researchers, and the graphics are adapted from the original design by Todor Doychev.

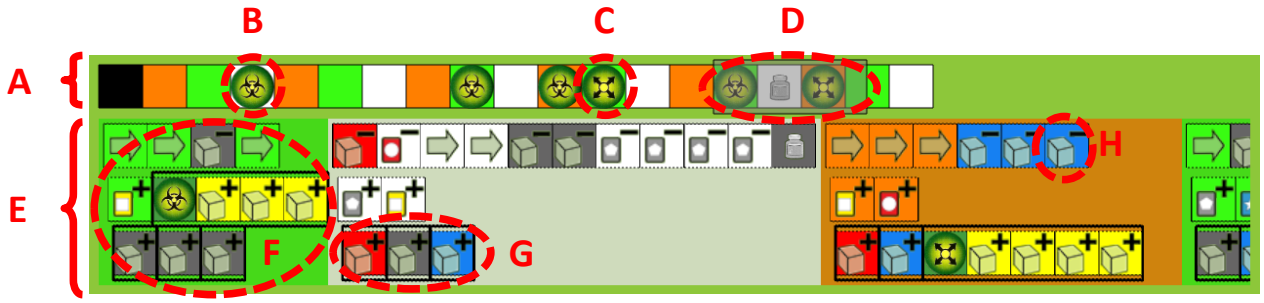


**Figure 2:** The interactive event timeline. (A) overview bar showing the players' turns so far with symbols denoting important game events, such as (B) epidemic and (C) outbreak; (D) viewport for navigating through the game history; (E) detail pane showing game events from the selected turns; (F) a player's turn in the game, consisting of three rows; (G) a row representing one phase in a player's turn; and (H) an event block representing an action carried out by either the player or the game, black bounding boxes showing related game events (symbols denoting the type of the event e.g., arrow for moving to different cities, bottle for discovering a cure, and +/- for adding or removing game pieces).

spread of diseases while making progress on cures.

Special events, called epidemics, happen repeatedly in certain intervals of time to make the game more challenging and interesting. Outbreaks of diseases may also happen if the game state is out of control. It is important for players to stay aware of these critical events so they can make effective strategies.

The digital game (Figure 1, right) provides automation to reduce manual workload and enforce rules. For example, the game automates the opponent's (the game board's) actions by placing disease cubes based on cards drawn and resolving epidemic events. This involves several steps of drawing cards, shuffling a deck of cards, and placing disease cubes. The game also handles setup and cleanup of the game pieces and other manual tasks to allow more time for players to discuss strategies.

## 2.1 INTERACTIVE EVENT TIMELINE

The interactive event timeline is designed to improve players' awareness of the automated action. It allows players to explore the previous game events, including both player and computer actions (Figure 2). It is composed of two main components: an overview bar (Figure 2A) and a detail pane (Figure 2E). The overview bar at the top provides a high level view of the game progression, and the bottom detail pane provides information for all the game actions happened during the selected turns.

The overview bar (Figure 2A) shows each player's turn in chronological order, color-coded by the in-game player colour (orange, green, and white). Symbols on the overview bar denote special events (epidemic and outbreak) that happened during the particular turns. Players can drag the grey viewport (Figure 2D) or tap on any player turn on the overview bar to navigate through the history and see the turn of interest in the detail pane.

The detail pane contains player turns currently selected (Figure 2E). Each turn consists of three rows corresponding to the three phases in the game (Figure 2F). The first row represents player actions. The second and third rows represent two types of automated actions: cards drawn for players and cities infected. Each block represents one game event (Figure 2H) with a symbol denoting the type of events. Related blocks are grouped in the same black bounding box. The colour of each block is from the colour coding scheme used in the Pandemic board game. When a game event block is selected, additional information may be displayed on the shared game board and/or within the detail pane. We will discuss the feedback placement in Section 3.

# 3. STUDY: OWNERSHIP & PLACEMENT

We conducted a study with two design factors related to the interactive event timelines in order to understand the trade-offs between different setups in a collaborative setting. The factors are ownership of the timeline and the placement of display feedback.

**Ownership**: Since there are multiple players, it is unclear who should control the timeline. One timeline can be shared among a group, or each player can have a dedicated timeline (Figure 3 and Figure 4). While one shared timeline may encourage participation and a higher level of collaboration, a dedicated timeline may better support independent work, such as brainstorming strategies. Morris et al. [8] found that while participants in a collaborative photo tagging application preferred individual replicated menu widgets, the shared centralized widget resulted in a higher level of collaboration. Our interactive event timeline allows players to explore historical events, so they may have different preferences or events of interest in seeing this history.

**Feedback Placement**: When players interact with the timeline, the information about the game event can be displayed on the

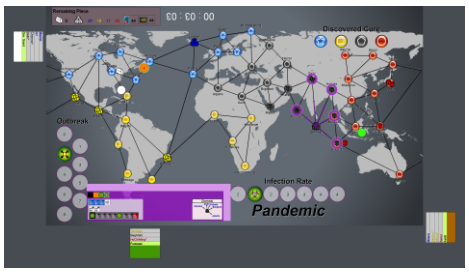


**Figure 3:** A shared timeline (movable and rotatable). The timeline color was chosen to avoid conflicts with player colors.

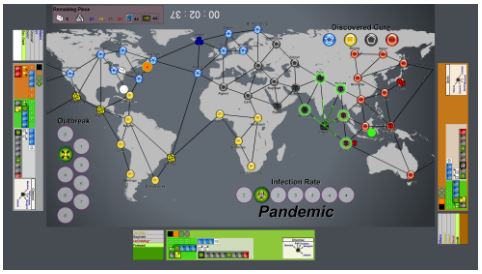


**Figure 4:** Dedicated timelines. They are color-coded by the owner's player color.

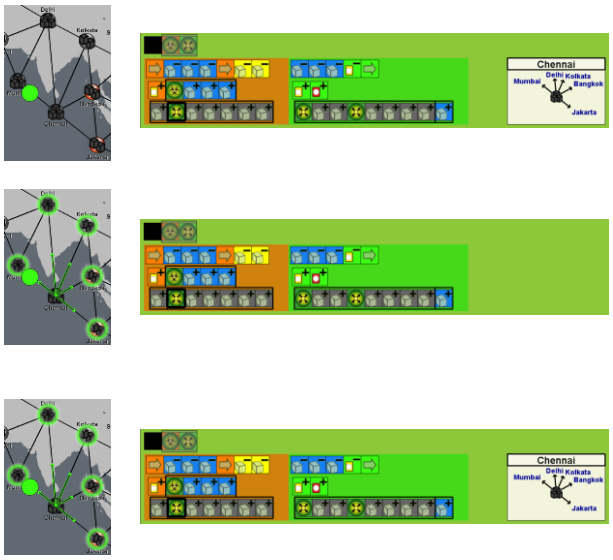


**Figure 5:** Comparison of feedback placements. (Top) on the timeline; (Middle) on the shared game board with color-coded animation highlighting the selected event; and (Bottom) at both the game board and the timeline.

timeline, on the shared game board, or at both locations (Figure 5). Displaying feedback on the timeline provides a consistent location to look for the information. Feedback on the game board provides more contextual information and may encourage collaboration. However, players may have to search for the feedback due to the large size of the digital tabletop, and players' distance to the interaction space. For dedicated timelines, the animation triggered by other players on the board may distract players from finding animations they invoked separately. Different feedback placement can provide various benefits; we thus include feedback placement as the second factor in our study.

# 4. METHOD

We used a 2 (Ownership, between-participants) × 3 (Feedback Placement, within-participants) mixed-design (Table 1) to study the impact of the different timeline design factors on players' situation awareness.

## 4.1 PARTICIPANTS

Thirty-six participants (23 male, 13 female, ages 22 to 36) were recruited through mailing lists and posters in the local community, and word of mouth. Participants signed up in groups of three, and all knew their team members prior to the study. All participants had prior experience playing the Pandemic board game.

## 4.2 EQUIPMENT & SETTING

Each group of participants was seated around a 55" digital tabletop computer in a laboratory setting. Two players were on the short edge, and one player was on the long edge of the tabletop, to avoid the situation of one player seeing the game board upside down. The screen was 3840 × 2160 pixels and the physical dimensions were 95 × 148 cm. The computer was running 64-bit Windows 7 using Intel® Xeon® CPU E5-1603 @ 2.80 GHz with 4 GB of RAM. Two camcorders were used to record the game sessions, and one was placed behind the participants while the other was facing participants.

| | | Ownership | |
|---|---|---|---|
| | | Shared | Dedicated |
| Feedback Placement | Timeline | 1 | 4 |
| | Game Board | 2 | 5 |
| | Both | 3 | 6 |

**Table 1:** Potential conditions based on different design factors.

## 4.3 QUESTIONNAIRES

We measured the players' situation awareness, gaming experience, workload, and general preference in each condition. There were two types of questionnaires. The first was a gameplay questionnaire, which consisted of PENS [10] for player experience, NASA-TLX [7] for workload, and questions on their awareness and teamwork. The second was a situation awareness (SA) questionnaire developed by three researchers for inter-rater reliability. We followed the steps outlined in SAGAT [6]. There were three sets of SA questionnaires with distinct questions. Each SA questionnaire had 6 questions in total with 2 questions on each level of situation awareness as defined by Endsley [5].

## 4.4 PROCEDURE

The study sessions lasted approximately 2.5 to 3 hours. Participants were first greeted by the researcher, and then signed consent forms and filled out background questionnaires. There were three parts to the study: *training*, *pandemic challenges*, and *full game*.

**Training**: There were two sets of training sessions. For both sessions, the researcher first explained the interface, and the participants played for 10 minutes. The first session was the no-timeline version of the digital game, and the players filled out the gameplay questionnaire afterward. In the second session, participants were allowed to practice on the same version they would see in the first condition given in the *pandemic challenge* phase.

**Pandemic Challenges**: Participants played through 3 conditions of feedback placement in counter-balanced order. Half of the groups were given a shared control (conditions 1-3) and the rest used dedicated controls (conditions 4-6). For each condition, the players were asked to start playing from the middle of a Pandemic game, and were given 2 rounds (2 turns for each player) to play. There were three initial game states, constructed from real gameplay with some controlled parameters, such as the number of critical events that happened and the number of cures discovered. The order of the initial game states was randomly chosen.

Players individually filled out post-condition questionnaires, which consisted of both the gameplay and the situation awareness (SA) questionnaires. There were in total three sets of SA questionnaires, and the order of the SA questionnaires was randomly selected. The same set of initial game states and SA questions were used across all groups. Participants filled out a preference questionnaire at the end of this phase.

**Full Game**: In this final phase, the participants played a configurable version (Figure 6). The configurable timeline allowed players to freely expand, minimize, and toggle the feedback placement at any time during the game. They were asked to play a full game and all the groups had the same card deck and initial setup. The participants filled out the gameplay questionnaire with a free form area for comments after the game.

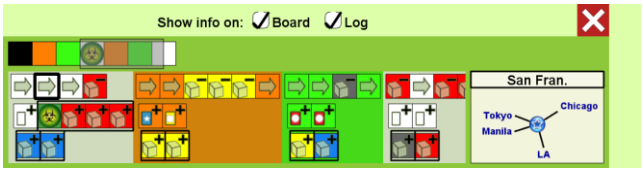


**Figure 6:** Configurable version with options to minimize and toggle feedback placement on the border.

Finally, the researcher debriefed the participants with the goal and details of the study, and conducted an unstructured interview to receive any additional feedback from the participants.

## 4.5 DATA COLLECTION

During the gameplay, we collected several types of data including video recordings from two different angles, screen recordings, computer logs, audio recordings, and questionnaire data.

# 5. PRELIMINARY OBSERVATIONS

At the time of writing, we are still analyzing the quantitative and qualitative data gathered. In this section, we present some of the preliminary observations.

**Ownership**: Groups in the dedicated condition used the timelines more frequently than groups in the shared condition. It may be that the shared timeline required more effort to pass around for others to see. For the dedicated timelines, players checked the new automation results after almost every turn.

**Feedback Placement**: Some players commented that the feedback on the game board helped them gain awareness of what other players are paying attention to. However, some players found that feedback on the game board can be very confusing, since a few players mistook the player-triggered animation as system automation. In terms of player preferences, players saw value in both placements of feedback. Some players preferred having feedback on the timeline since they did not need to search for it on the game board, and some players commented that feedback on both the game board and the timeline was the best setup.

**Configurable Timeline**: Even though players could switch the setup at any time, most of the players seem to discover their preferred setup at the beginning of the game and maintained this setting throughout. Players exhibited different behaviour when viewing the timeline. While some players opened the timeline when needed and closed it once they were done, some players always kept it open. Some players did not use the timeline, but instead got information from other players. A few players only opened and started using the timeline toward the end of the game, which may suggest that the timeline becomes more useful as the game state progresses. Finally, players in the shared condition appreciated the configurable version since they got a dedicated timeline for themselves.

# 6. FUTURE WORK

Further data analysis on the situation awareness questionnaire is warranted to fully understand the impact of ownership and feedback placement on players' situation awareness. Moreover, conducting video analysis on the configurable version will help us understand how players make use of the timeline as a group to gather awareness of the game state in a more realistic setting. Finally, we will also conduct data analysis to understand the setups impact on gaming experience, workload, and preferences.

# 7. ACKNOWLEDGMENTS

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