ABSTRACT

The different stakeholders in the sports domain rely on the analysis and presentation of sports data to derive insights. In particular, sportswriters construct game stories using the statistical information; fans share their viewpoints based on the real-time stats while watching the game. In this paper, we explore how these stakeholders construct data-driven sports stories. We began by observing a sportswriter, analyzing published sports stories, and characterizing 1500 fan comments about particular sporting events. We found that their story needs were similar in some respects while quite different with respect to others. Based on the findings, we implemented two exploratory prototypes: GameViews-Writers for sportswriters to quickly extract key game information and GameViews-Fans to support a real-time data-driven game-viewing experience for fans. We report insights from two user studies conducted with four professional sportswriters and eight sports fans, respectively. The results led to a number of future research directions.

CCS CONCEPTS

- Human-centered computing → User interface toolkits; Information visualization; Visualization toolkits.

KEYWORDS

Sports data visualization, storytelling, user interface

1 INTRODUCTION

Life Needs Sports. 1 Sports pervade our society and watching sports is an integral part of our lives [42]. Particularly, in this big data era, most aspects of the sports industry have discovered and benefited from the power of data [31]. Predictive analytic models have been developed to inform sports team strategy [30] and data management systems are used to inform decision-makers and enable them to increase revenues and help their organizations gain a competitive advantage [2]. Prior studies also show that sports fans, especially American fans, are obsessed with game statistics [3]. This interest is likely to increase given recent upward trends in fantasy sports and new laws regarding sports betting [13]. However, the current methods for representing game data do not adequately incorporate the needs and support the activities of different sports data stakeholders.

In this paper, we focus on sportswriters and fans, which are essentially two sides of the same coin. Sportswriters rely heavily on websites, such as ESPN 2 and CBS Sports 3, to write "recaps" (i.e., short reports) for each game [29]. These websites routinely present visualizations and box score tables to summarize the game and present statistical information (See Figure 1). Similarly, sports fans are actively gathering game data from television, sports websites, and social media and sharing their observations as they watch sporting

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1 ESPN’s new brand campaign.
2 http://www.espn.com/
3 https://www.cbssports.com/
We contextualize our work by introducing sports analytics with visualization, discussing related work in visual storytelling, and summarizing previous research on sports fans' game-viewing behaviors.

Video and Visualization Based Sports Analytics

Sports analytics is the use of advanced quantitative methods with massive sports data to empower sports teams and other sports stakeholders to make better decisions [1]. Researchers have extensively explored the use of visualization in the sports domain [4]. Perin et al. presented a comprehensive survey on sports data visualization [36]. Tools such as SoccerStories [35], iTTVis [43], SportVis [11], and GameFlow [10] were designed to support analysis and exploration of soccer, table tennis, baseball, and basketball game data. Interactive visualization has also been used to analyze players' performance [5, 28] and reveal game insights using multidimensional data analysis [10].

Annotated Visualizations

Storytelling enables visualization to convey information in a more effective way [17]. To explore the use of storytelling in visualizations, Segel and Heer examined the design space in narrative visualization and summarized the commonly-used seven genres [38]. The annotated chart is a commonly-used genre in visual storytelling aimed at supporting understanding of a graph by "graphically" guiding readers' attention to visually salient features [38]. The text annotation incorporated in the visualization also helps explain what the data means and is of particular importance in journalism [8]. These findings inspired researchers to develop automatic annotation systems for aiding chart reading [26] and supporting understanding of data structures [24], to annotate stock market visualizations [22], and to explore temporal visualizations [7]. Researchers have also explored the social space of narrative visualization [19]. Previous studies indicate that combining conversation and visual data analysis can help people more deeply and broadly explore the given data representation [19].

Inspired by prior work, we tightly coupled the visual representations of the game data with narrative annotations aiming to provide "at-a-glance" statistical information to sportswriters and fans and to support their construction of stories around the data.

Sports Fans Game-Viewing Behavior

Understanding fans' behaviors is a key construct in business-focused relationship marketing and can be used to facilitate their interaction [39]. Psychologists have conducted extensive studies to understand the motivation and behaviors of sports fans [9, 40]. Conceptual models were also proposed to classify fans into different types so that specific marketing strategies and product design can be offered for the different types of fans [23].

Many researchers have focused on fans' game-viewing behaviors through investigating fans' chat interaction while they are watching sports events. Earlier works have shown that more and more sports fans are engaging in chatting and...
becoming more socially interactive while watching sports games [16]. People also feel more comfortable talking with strangers during the game [12], and fans enjoy sharing group identity associated with specific teams [27]. Studies also show that chat enables fans to develop interpersonal relationships with other co-viewers [41] and has the potential to improve the game-viewing experience [18]. The generated chat data from fans has been used to understand fans motivations [25, 39], develop strategies for advertising [20], and even summarize the sports event [32].

Our study advances these earlier findings by collecting and characterizing 1500 fans comments in the context of informing the visual interface design to support the game-viewing experience and fans’ collective narrative construction.

3 DESIGN REQUIREMENT ANALYSIS

In this section, we report the design requirement analysis for sportswriters and fans. Based on the findings, we derive several guidelines for designing visual interfaces to support data-driven storytelling for sportswriters and fans.

Gathering needs of sportswriters

We began by observing a professional sports journalist aiming to understand the process involved in the writing of a basketball game recap, in particular, we were interested in how sportswriters use sports data to construct the stories. We then conducted a systematic analysis of 40 basketball stories to characterize what types of game data are generally reported.

Observation. Prior research reports that sports journalists normally refer to box score tables or visualizations to find the necessary statistical information for writing their stories [21]. To confirm this argument and get a first-hand understanding of how professional writers construct their stories using sports data, we observed a professional sports journalist carry out this process of experiencing a game and writing the corresponding basketball recap. The journalist had 10 years of experience with sports-story writing. We first watched a college basketball game with the writer and observed his routine for constructing the story. After he submitted the story, we asked him some follow-up questions to glean more insights into how we can better represent data to support him constructing stories.

We divided the observed writing process into three stages. Before the game, the writer received a document that included the recent performance statistics of the two teams and all the players. He also built a simple template that included the layout of the article. During the game, the writer observed real-time stats through statBroadcast\(^4\), a real-time stats tracker. He specifically paid attention to and noted the salient elements such as a big difference in field goals and a player’s career-high score. After the game, the writer first organized the notes he took during the game, then he checked the box score table, play by play, and visualization charts on the ESPN website and statBroadcast to find additional interesting statistical insights. He then completed the story.

Characterization of Basketball-game stories. To identify the common statistical information that basketball writers potentially include in their stories we constructed a corpus of 35 basketball recaps from the ESPN website and 5 recaps from other local news websites. Specifically, the analysis sought to answer two questions: (1) What are the types of statistical information usually included in basketball sports stories? (2) What are the common key events described in basketball sports stories?

Method. 40 recent basketball game recaps were compiled into a corpus. The Associated Press (AP) covers all the NBA and NCAA basketball games and multiple media outlets including ESPN publish the AP basketball game recap as the game recap on their respective websites and media outlets. The majority (35/40) of this corpus were stories produced by AP news and published by the leading sports media outlet, ESPN. The remaining (5/40) came from heterogeneous sources such as posts from college media outlets and local news publications. The corpus covered all 24 NBA teams and 5 college teams. We also used game results as criteria to capture a broad range of stories. Specifically, we included 15 games with a final score difference less than or equal to 5 points, 10 games decided by fewer than 10 points but more than 5 points difference, and 15 games decided by more than 10 points or more. We also included 3 games that went into overtime.

To extract and characterize the statistical content of the corpus, we individually reviewed a set of stories and summarized the characteristics found in them. Specifically, two coders first extracted and analyzed the statistical content in five stories, which resulted in the initial categories for all statistical information. Over several iterations, the coders refined the categories and identified a set of codes to represent them. Five stories were then coded independently by the two researchers and then the codes were updated to reconcile the differences between two coders. The remaining stories were then coded independently.

Characterization Results. We summarized the statistical information that is commonly included in basketball game recaps into three categories: individual player statistics, team statistics, and key events. Note that all the recaps we analyzed included all of the following three category instances.

- **Individual player stats** Sportswriters always highlight a player’s stats when she or he is a stats leader in

\(^4\)http://statbroadcast.com/
We chose the comments from Reddit in particular because we collected and characterized 1500 "live game" comments. The user-community is very active, the comments in 1500 comments. The coding process was identical to that carried out on the basketball recaps characterization described in section 3: two coders first informally and individually studied sports fans behaviors

Motivated by previous practices where social media comments were used to explore fans’ motivations and behaviors [14, 39] and intended to cover as many subjects as possible, we collected and characterized 1500 "live game" comments from fans aiming to understand what do sports fans care about when they are watching the game and constructing the comments.

We collected all the fans comments from four NBA game threads at Reddit, the most-visited social news website [6]. It is comprised of thousands of topical-based user-created subreddits. The NBA subreddit, for example, attracts thousands of basketball fans who make posts and comments regularly. We chose the comments from Reddit in particular because (1) the user-community is very active, (2) the comments in a game thread are specific to this particular game, and (3) all posts and comments are easily accessible through the Reddit API. We selected the comments from the 2017 NBA Finals games as they had the highest fan engagement. For each game thread, we only collect user comments with timestamps from the game start to end, indicating they took place during the competition. We collected only new comments rather than comment replies in an attempt to make the data collection and analysis manageable while still covering the entire duration of the game.

To characterize sports fans comments, we conducted a qualitative analysis of the topical aspects of the collected 1500 comments. The coding process was identical to that carried out on the basketball recaps characterization described in section 3: two coders first informally and individually analyzed a small set of 150 comments. Over several iterations, various themes such as "statistical related" comment and "game expertise" comment emerged. A set of codes that describes these themes was created and discussed by the two coders. 200 more comments were then randomly drawn from the corpus and coded independently and the coding protocol was updated after a discussion of the disagreed upon comments. The remaining comments were then coded by the primary coder.

The findings revealed a number of themes that emerge from the posted comments of fans as they watch the basketball games. These themes advanced our understanding of how to better support sports fans with game information. We presented the characterized themes and the corresponding percentage in the 1500 comments along with examples below. It should be noted that themes were not mutually exclusive.

- **Player/team Appraisal (42.7%)** Comments directed toward a player, including praise or critique of a player’s or a team’s performance. Comments of a player or a team could also be made in sarcastic or teasing manner. For example “Jr has some of the lowest iq I have ever seen from an NBA player.” and “Warriors is the only dream team, period.”

- **Game Observation (26.4%)** Comments that reflect an observation or view towards the game, including describing what’s happening and expressing opinions over the game trend or a particular play. Examples include “Put the bench back in. At least they play with energy.” and “Love’s inability to hit his threes is destroying any shot the Cavs have at winning this series. These are wide open looks he is missing.”

- **Personal Passion (15.8%)** Comments that express the sentiment of the team, players, and personal feelings. Examples such as “I’m not even mad, just disappointed.” and “Sports are weird.”

- **Statistical Information (13.9%)** Comments that include statistical information of a player, team, or a certain time period. Examples such as "31 points already on 11-13 shooting. Outrageous" and "Cavs 30 - Dubs 29"

- **Game Decision-maker (8%)** Comments centered on judging the performance of both teams’ coaches and/or referees in the game. Examples such as "Starting Javale was a fantastic adjustment by Kerr" and "these blind refs"

- **Peripheral Subjects (3.9%)** Comments regarding peripheral elements of the game, including commentators, game commercials, and the audience. Examples such as "Paul Pierce is terrible as an analyst" and "Anyone else despise this Facebook commercial?"
Findings

**F1. Similarities.** While our intention was originally to study the two target user groups separately, we were intrigued by the similarities that emerged with respect to how sportswriters and fans use game data during the story construction. The ‘statistical information’ comments from fans covered all the three stats categories that were extracted from the recaps. For example, if a player got a very high score, sportswriters would include this in the recap and fans also tended to share this information. The stats included in the comment “that’s a 13-0 in last three minutes, Warriors is killing it” and “so the 3-2 at the beginning of the first quarter is our only lead in this final game??” are also highly likely to be included in a sportswriters game recap. In addition, sportswriters and some fans also tended to extract game insights by doing additional stats analysis. The writer told us “I will always try to dig into the numbers and see if I can find something interesting.” For example, consider this excerpt from a game recap. “Kevin Durant scores at least 8 points in every quarter.” This stat is clearly not reported directly, but derived by the writer. We also observed that fans like to share comments involving deeper stats analysis as well. For example, one fan commented “Kevin Durant has at least 10 points in the first three quarters, MVP = stable.”

**F2. Differences.** While there were some similarities, sportswriters and fans needs differ in some significant ways.

**F2.1. Sportswriters tend to focus more on inspecting why or how.** In addition to presenting obvious stats in the story, sportswriters are also expected to deliver insightful analysis in game recaps. For example, if a team came back from a big deficit, writers would like to inspect every play in this period and extract interesting facts for a story. As the writer said, “I’m always include runs in the story, but I’d also like to know what happened in the run to see if there is something interesting.” On the other hand, fans tended to share the direct statistical information with less exploratory analysis of the particular event of interest. For example, “LeBron already got 30 points I hope he can save us tonight.”

**F2.2. Fans focus more on particular plays.** A majority of the ‘Game Observation’ comments were accompanied with a particular play in the game, such as a score, block, or foul. We also observed lots of ‘Personal Passion’ comments by fans inspired by a particular play. For example, a fan wrote “smoooooooo” after Stephen Curry made a long three-pointer. However, sportswriters would typically incorporate a play in the story only if it belongs to a ‘key event.’

**F2.3. Game-viewing and sharing is a more social experience than constructing a game recap.** Previous studies show that chat interaction during sports game viewing enables fans to develop interpersonal relationship [18] and help them better understand the content [41]. As shown in the comments characterization result, fans shared their opinions about the game, players, teams, and even commercials and the audience at the game when they were watching the game. On the contrary, the writer mentioned and would sometimes integrate some interesting comments from Twitter, or about the audiences, it is still much less prominent than that seen in the Reddit comments.

**F2.4. Use of Game Video.** Previous research shows that sports fans envision useful functions such as “skip commercials” and “go back to see specific plays” in the game video [33]. Some of the comments echoed this result saying “I wanna see the beautiful moves again.” These findings indicate that fans would like to interact with the game video. On the contrary, writers rarely check the game video while writing the story after the game.

**Design requirements.** Based on the the related literature and the previously presented analysis of our target users, we distilled a list of design elements to explore in an interface for sports story construction. In an attempt to bound the scope, we focus on four as below in particular in this paper:

- **R1. Providing at-a-glance stats information for sportswriters and fans accordingly.** The interface should directly show the key information that is of interest to sportswriters and fans (F1).
- **R2. Providing more fine-grained stats analysis for sportswriters.** The interface should provide more fine-grained analysis options for sportswriters who often need to dig deeper to understand the “why” (F2.1).
- **R3. Enabling real-time chat for fans.** The interface should support chatting functions to enable fans to share opinions in real-time and to tie those opinions to the real-time data (F2.3).
- **R4. Supporting game video replay for fans.** The interface should enable fans to easily navigate back the video and check previous plays that interested them (F2.4).

4 EXPLORATORY PROTOTYPES

In an attempt to explore the proposed design requirements, we designed two proof-of-concept exploratory prototypes, GameViews- Writers (Figure 2) and GameViews-Fans (Figure 3). In this section, we discuss the design and use cases for both of the prototypes.

**GameViews-Writers**

Based on the design considerations for sportswriters, we designed a prototype to support sportswriters in writing
basketball-game stories. GameViews-Writers was designed as a web application that automatically collects data from the ESPN website and renders a front-end interactive visual representations as shown in Figure 2.

**Example Use Case.** Figure 2 shows the GameViews-Writers prototype for a game between two NBA teams: the Portland Trail Blazers and the Oklahoma Thunder. It consists of four parts: an annotated game flowchart, a box score table, a temporal player statistical chart, and a player shot chart with the spatial layout. Consider the following scenario for how a sportswriter would experience the prototype.

Suppose Maria is a basketball writer who works for a local newspaper in Portland, Oregon. After watching the Blazers beat the Thunder tonight, she needs to submit a game recap for the newspaper’s website. She finds the game on ESPN and copies the ESPN URL. She opens GameViews-Writers, and pastes the URL into the search box. GameViews-Writers updates to show this game.

At first glance, she sees that it was a tight game with the two teams swapping leads several times during the game. The Blazers won the game 108–100. She is interested in finding out what happened during the game, so she scans Figure 2 A and finds that the Trail Blazers came back from a big deficit with a 13:2 run at the beginning of the second quarter, then the Thunder tied the game with a similar run at the end of the second quarter. She wonders what happened in the Blazers’ run, so she clicks the first grey area corresponding to the run and sees the shot chart update to only show the shot of this run. She finds that in this run, the Thunder missed two 3-pointers and only made one shot in the paint area while the Trail Blazers made three shots. She notices the Thunder led at the beginning of the game and the Trail Blazers dominated in the last quarter. She also finds after the final lead change at the middle of the third quarter, the Trail Blazers kept the lead and won the game. She wonders who took the shot that led to the final lead change, so she clicks the red dot, I, and the note at the top of the flowchart shows “CJ McCollum makes 25-foot three point”.

Maria also wants to know who were the top performers in the game, so she goes to Figure 2 B and clicks PTS, REB, and AST to sort the table and find who led the Trail Blazers in points, rebounds, and assists respectively. She finds Russel Westbrook led the Thunder in scoring. She wants to see his shot distribution so she clicks his name in the table and sees the shot chart update to only show Westbrook’s shot. The player stats chart also updates to show his shot in detail. She
finds Westbrook made most of his shots at the end of the fourth quarter and he did not take many 3-point shots. She can click the Team button to compare all detailed statistical performance of the two teams. She can also hover over any shot in the shot chart and the player stats chart to see the description of a particular shot.

As such, GameViews-Writers has supported Maria in (1) finding the key events in the game; (2) finding salient individual player and team statistical information; and (3) examining the details of each player of interest, the runs, and each quarter in the game.

Annotated Game-Flow Chart with at-a-glance Key Events (R1, R2). A point of interest, or POI, is referred to as an annotation that describes a single aspect of the underlying dataset [7]. For example, in a time-series line chart, POIs may include the maximum and minimum points. Based on the recaps characterization results, the POIs we collected for the game included all the key events (e.g. home/away team’s largest lead and time of that lead, final lead change, and runs.) Given text annotations can visually guide participants to salient time series data features and/or elements, GameViews-Writers presented all the POIs as icon annotations in the game-flow chart. We designed annotation placement as shown in Figure 2 A rather than directly embedding the text into the chart (e.g. Contextifier [22] and TSI [7]) because the description of some game events could be very long and it could potentially result in unexpected overlapping. Note that participants can click the annotation to explore its details.

Box Score Table (R1, R2). As shown in the two upper views in Figure 2 B, the box score table includes the players’ and teams’ statistical information. Participants can click the head of the table to sort by each type of statistic. To support fine-grained analysis, participants can also click a player’s statistical data; the player stats chart will be updated to show the corresponding temporal information.

Player Stats Chart (R1, R2). As shown in Figure 2 C, we chose a temporal layout to support the exploration of players’ statistical information. Each dot represents a statistical event such as a shot, rebound, or assist. Participants can hover over the dot to examine the description of this event. Colors correspond to respective teams. To support fine-grained analysis, the player-stats chart is linked to the box score table and will be updated when the user selects a statistical type in the box score table.

Player Shot Chart (R1, R2). As shown in Figure 2 D, the player shot chart includes all the shots in a spatial layout. Each dot represents a shot and participants can hover over the dot to examine the description of this shot. We again use color encoding for the respective teams. To support fine-grained analysis, the shot chart is linked to the other two charts and is updated when an annotation is selected in the game-flow chart or a player name is selected in the box-score table.

GameViews-Fans

We designed another web-based exploratory prototype GameViews-Fans to embody and explore the summarized design needs for sports fans. The primary interface is shown in Figure 3 including four coordinated views: the upper left view is the live game video; the upper right view provides an annotated real-time visualization; the bottom left view shows play-by-play descriptions and customizable leading players and team statistics; the bottom right view provides a chat area displaying fans comments. Here we describe three main features of the interface: real-time stats representation to show at-a-glance stats and support fine-grained analysis, live game video navigation to enable replay of previous plays, and collaborative discussion to engage fans in real-time chat.

Real-time Stats Representation (R1). We followed the practice of GameViews-Writers to present all the game events in an annotated visualization that updates to reflect the real-time statistical information. To support fine-grained analysis, we provide game event filtering options including timeouts, score, rebounds, turnovers, and fouls. Participants can select a player from the drop-down list and a game event option to filter the visual annotations. For example, if a user wants to check Kevin Durant’s score events, she can select Kevin Durant and click the “score” option to see all annotated score events by Kevin Durant. She can then hover over each annotation to inspect this play’s description within a tool-tip.

We also provide a customizable stats table in bottom left view to show at-a-glance statistical information of game’s leading players and team. For the leading players’ stats, participants can specify sorting criteria such as score, rebound, and assists from the drop-down list. They can also select a particular player to check his stats.

Live Game Video Navigation (R4). We also provide a view for re-experiencing a previous play. We chose to tightly couple annotation visualization and play-by-play text with the game video. As a user watches the game, he or she can double-click an event annotation from the visualization or a play-by-play description to navigate the game video back to this particular play. Clicking the “Back to Current Game Time” button located above the game video will then navigate the game back to the live game.

Comment Labeling (R3). Motivated by [19] and to tightly tie the comment to the game data, we we created a “labeling” mechanism. Comments are shown on the bottom right view and grouped into linear threads (Figure 3 D). Each comment shows the author’s name, comment time, comment text, and a label, such as particular player, team, or game.
Figure 3: GameViews-Fans prototype showing an NBA game between Warriors and Cavaliers. A) shows the live game video and the current play description. B) is an annotated game flow chart where red dots annotate the selected player’s play events. C) shows the play-by-play descriptions and customizable statistic table for the leading players and teams. D) is a chat box where users can send and read labeling comments. We intentionally covered real users’ names.

event. Clicking on a label attached to the comment will filter the chat window to show all the comments with this label. The player label is automatically added if the comment includes a player’s name. Participants can also add player and team labels by selecting a player name or team name from the drop-down list. Clicking a game event from the flow-chart visualization or play-by-play text will automatically add the corresponding game event label to the comment. Upon submission, the comment text and its labels are sent to the server and the comment listing is updated. As such, “Comment Labeling” supports participants with 1) associating comments to particular players, teams or game events, and 2) filtering comments by labels to inspect some particular comment facet.

5 USER STUDIES
We conducted two user studies of the prototype designs to further explore how well our design guidelines meet the needs of writers and fans and how to improve them for future iterations. In particular, we were interested in: (i) gathering the impressions of sportswriters and fans with GameViews-Writers and GameViews-Fans, respectively, to improve our designs and (ii) to further study how sportswriters and fans use the interfaces to construct their stories.

GameViews-Writers
To study the the design elements in GameViews-Writers, we chose to compare GameViews-Writers with the ESPN website for a set of exploratory tasks such as finding the player with most rebounds and who contributed most to the comeback in the third quarter. The games between the Trail Blazers and Thunder 5 and between the 76ers and Bucks 6 were used as the example games in our study and the data corresponding to the games were visualized on both the GameViews-Writers and the ESPN website. We recruited four professional basketball writers, two male and two female, with an average of six years of experience with writing basketball game stories. Three out of the four writers typically used the ESPN website for checking basketball game statistics while one writer typically used StatBroadcast 7.

We asked participants to experience and use GameViews-Writers and ESPN and also to retrieve the stats included in the exploratory tasks. We asked them to think aloud as they navigated the interface. We then asked the writers to

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5http://www.espn.com/nba/game?gameId=400975687
6http://www.espn.com/nba/game?gameId=400975693
7http://statbroadcast.com/
freely explore the GameViews-Writers system for an additional amount of time and reflect on the potential of using the system when writing basketball stories. Finally, we asked participants to rate the visual clarity of the annotations, how easy it was to use, and how easy it was to learn to use the prototype using five-point Likert scales. We also conducted semi-structured interviews with participants post study to gather their likes and dislikes about the prototype and what other features they would have liked to see on the interface. The study lasted 30 minutes for each participant and they were compensated with a $20 Starbucks gift card.

Perception and Usage of Writers
We summarize findings from the user study of GameViews-Writers in this section.

Comparison with ESPN. All the 4 writers thought the annotations were very salient (3 out of 4) or salient (1 out 4). All the writers thought GameViews-Writers was either very easy (3 out of 4) or easy (1 out of 4) to use. Three of them said they prefer GameViews-Writers to the ESPN website for future statistical-information-seeking. The other writer said he would prefer GameViews-Writers if the author could add the suggested improvements. The sportswriters preferred the prototype for several reasons. First, participants preferred a "all-in-one" tool to support them in story construction. One writer explained why she valued GameViews-Writers more, "I like it because I can find almost everything I need in a single page, unlike ESPN, I have to navigate back and forth if I want to find more information." Second, sportswriters liked the visual representation and interaction design in the prototype. Third, our participants also mentioned they preferred the "sortable box table" over ESPN’s static table.

GameViews-Writers helped sportswriters find the needed stats more quickly. During the user study, we asked participants to complete a set of stats-retrieval tasks. We found that most sportswriters completed the tasks somewhat quickly with the GameViews-Writers compared with the ESPN website. The participants expressed that GameViews-Writers helped them find the needed stats information easily, "...I can get most of what I need in the first glance...".

Interactions enabled sportswriters to extract more insights. The participants approved of the linking interactions in GameViews-Writers. Once they were familiar with the prototype, the participants tended to use the interaction features extensively. The most-used interactions were 'clicking a player name in the box table to see the updated stats chart and shot chart to check when and where the player scored.' In experiencing the interactions, the participants found that they were able to find some game insights that they were unaware of. As described by a sportswriter with seven years experience of publishing basketball recaps for a local newspaper, "I noticed he scored all the four corner three-pointers, but missed most of the jump shots from the top of the circle, this is definitely something I can write about."

Suggestions on integrating more statistical information and usability. One sportswriter expressed the need for integrating both teams' recent game results: I like the team comparison table, but it would be great if you can also have the recent game results for both teams, so I can also compare the recent performance of the two teams. Another writer preferred more numeric information in the visualizations (e.g., shot chart and stats chart). Participants also pointed out a potential usability problem regarding the inadequacy of the attention brought to signify important changes on the interface. The writers also suggested adding additional functionality that they could benefit from. I found I can hover over the game flow chart to see play by play in both ESPN and your system, but it would be useful if it supports click a point and lock the play, so the play by play note won’t go away after I move my cursor.

GameViews-Fans
We ran another user study with eight basketball fans (2 graduate students, 3 researchers and 2 software engineers from a well-known research institute, and 1 product manager from a sports-related startup) to gather their feedback on the prototype developed for GameViews-Fans. We selected the 2017 NBA final game between Golden State Warriors and Cleveland Cavaliers because it had a significant number of comments on Reddit. We manually selected 40 comments from this Reddit game thread and added them into the prototype with the corresponding timestamp so that the first participant could view some existing comments from other fans. We followed the practice in a previous study [19] where late participants could view the contributions of previous subjects but not vice versa.

After a brief tutorial of system features, participants were given a list of tasks aiming to make sure they were familiar with all the system features. These tasks covered all the views and basic designed interactions in the interface, such as ‘replay Kevin Durant’s last score event’ and ‘find Warrior’s score leader for now’. We then navigated the game to the beginning of third quarter and let participants start watching the complete third quarter game with this prototype however they liked. We chose the third quarter since it was the most dramatic period of the game and we expected the participants would feel more engaged. An observer was present answering questions and taking notes and a think-aloud protocol was used. We wrapped up the study with an exit questionnaire regarding their experiences. Participants were asked to rate on a 5-point Likert scale on statements including satisfaction and usefulness of each of the designed
features. A full list of exit questionnaire was included in supplemental materials. The study lasted 35 minutes for each participant and they were compensated with a $15 Starbucks gift card.

The Perception and Usage of Fans

We summarize findings from the user study of GameViews-Fans in this section.

![Figure 4: Results of post-study questionnaire. 0 - 5 in x-axis stands for 5 Likert scale rating from Strongly disagree to strongly agree. Mean values are shown, error bars indicate standard deviation.](image)

Visitation and Navigation on the prototype. We first wanted to understand how participants use and navigate the GameViews-Fans interface. All the participants began with watching the game video. A few then started to check statistical table and went to chat section to see what others have said. Many participants glanced at the statistical table after every play. They also checked every popped up comment from other fans. Viewing comments often sparked their interest to make a new comment. It was common practice for fans to check play-by-play information or the visual representation to replay a recent play interesting to them during commercials and timeout. Most of the participants tended to make a comment with the event label after an impressive play. Other behaviors included routinely browsing a player’s statistical information after he scored or fouled. Another notable practice was replaying the plays that they missed. In reference to the visitation behaviors on GameViews-Fans, the most-used features were statistical information including checking stats table and investigating the visual representation, both of which occupied a large proportion of the usage logs. The second most-used technique was chatting, in which fans mainly filtered and sent comments. While video replay was the least-used feature, it was nevertheless performed by every participant.

Participant comments on GameViews-Fans. Generally, participants felt engaged with the chatting function in GameViews-Fans. There were two participants who chose “not sure” with regards to the statement of ‘if they felt engaged with the conversation.’ One of them explained, ‘...usually I like to watch the game casually, I don’t like to chat with other people unless he is my friend.” Participants also perceived the labeling feature was helpful for the chatting function. One participant didn’t make many comments but still rated ‘agree,’ saying “I didn’t use the labeling function too much, but I think it’s useful if I just wanna see comments about a player.” All the participants appeared to understand the labeling mechanism clearly. In total, 39% of the comments were sent with labels, where 70% of the labeled comments were tagged with a game event. We found that the comments with labels were relatively short and focused on expressing their sentiments, such as “awesome” and “damn” followed by “Klay Thompson made a 27 feet 3 pointer.” Fans also used labels to filter out comments that were not interesting to them, as one subject said, “I don’t wanna see any comments about Warriors, I only want to chat with LeBron fans.”

We collected 48 comments from eight participants in total. We observed two contrasting fans behaviors: one group with five participants shared more than 7 comments each while the rest of fans sent less than 3 comments each. Based on the coding rubric used in comment characterization, we found 42% of comments involved expressing their Personal Passion, 29% of the comments were Game Observation, 27% particularly related to Player Appraisal, and only 2% concerns Game Decision-maker. We didn’t find comments related to Peripheral Subjects such as commentators and audience. Participants tended to express their sentiments after a nice ball with relatively short comments, such as “nice shot” and “saw it coming.” were sent after Kevin Durant shot a three pointer. We also observed that the participants liked to share game observations during timeout or commercials. The only comment on the referees was to complain that the whistle was too late.

Perception on stats data representation: similarity and difference. The real-time statistical information presented alongside the live game was favored and used by all the participants. The high variance value on the use of stats table, as shown in Figure 4, was because some of the participants were satisfied with the leading players’ statistical information. This leads to few user actions on selecting or filtering players on the interface. At the same time, we noticed polarized opinions on the visual representation of the game data. Three out of eight participants were particularly impressed by the customizable annotation, “I like the way you integrate all the stats in the graph, it’s very straightforward and helpful.” However, other participants didn’t think the visual information was helpful, “I think you can totally remove the visual part and make the video bigger” and “I won’t have time to click the visualization multiple times when I’m watching the game.” The relatively-low rating score for the visual stats and the feedback imply that our visual designs can be improved from the perspective of participants who are not very interested in stats.
We suspect the reason why some participants underestimated the visual representation of game data is that it didn’t provide the at-a-glance information that they needed in an intuitive way. As a subject said, “...will only take a glance of other views instead of doing some clicking to find more.”

Suggestions on game data visual representation, coupling interaction with video, and chatting function. We obtained a variety of feedback from sports fans. Some advocated to replace the visualizations in the GameViews-Fans interface with a bigger video. Some were passionate about using the visual representation and suggested adding even more information and functions such as players’ history stats. All the participants were intrigued by the coupling between game data representation and game video. They also suggested other coupling mechanisms such as linking comments and the video, “I think it’ll be cool if you can link the comments with the video, like selecting a comment to navigate the video back to the play related to this comment.” Participants were also engaged in the chat interaction as they watch the game. They suggested integrating more functions into the chat window, such as emojis, up-votes and down-votes, quote and reply to a comment, and even embed chat into the video as the form of “danmaku”.

6 FUTURE DIRECTIONS AND LIMITATION
The findings from the two user studies echoed the proposed design requirements and enhanced our understanding of data-driven sports storytelling. The visualization and interface were designed more generally for rich temporal and spatial data collected between opposing teams which are typically present in many sports domains. Thus we believe these design ideas can be further applied to other sports domains such as soccer, American football and baseball. In this section, we discuss the research directions and limitations.

Curate at-a-glance data representations on visualization design. Although the participants found the designed visual elements in GameViews-Writers interface to be effective, we obtained opposite opinions with regards to using the visual representation to support fans’ game-viewing experience. We suspect the reason why some participants underestimated the visual representation of game data is that it didn’t provide the at-a-glance information that they needed in an intuitive way. As a subject said, “...will only take a glance of other views instead of doing some clicking to find more.”

Thus, further research is clearly needed to design visualizations that provide the accurate ‘at-a-glance’ information in a more direct way.

Explore more coupling interaction mechanisms. The coupling interaction between data and visualization and different visualization views has been proven to be effective in helping sportswriters quickly extract insights from game data. Fans were also intrigued by the interaction between the data and game video, they also suggested more interaction mechanisms such as binding video with comments. Along these ideas, there are appealing possibilities to generalize this coupling interaction to more visualization designs. For example, Metoyer et al. [29] demonstrated the technique of linking text and visualization using text mining approaches. We hope our findings will inspire others to develop innovative coupling techniques for visualizations.

Support generating data stories automatically. In both of the user studies, writers and fans mentioned the potential of the two prototypes on generating data stories. As a writer described, “I can use it to select some representative chart in each period and then export it as a web page, this can be a game story!” Similarly, a fan envisioned, “I think you can save all the video clips that I replayed, then you can literally have a highlight video of this game.” Inspired by this and based on previous narrative visualization authoring tools [15, 37], how to customize the prototypes into a sports data story authoring tool for our target audience could be a promising future direction.

Our user studies had several limitations. We studied both GameViews prototypes on a single game. Testing on additional games is recommended. The analyzed fans comments and recaps may be limited and not cover all themes and stats information. The user study with GameViews-Fans prototype was done by simulating the game viewing experience. Deploying the interface and try with real live games are likely to provide more implications on visual design for real time sports viewing experience. As our future work, we plan to integrate live video into the system and test it in-the-wild.

7 CONCLUSION
We explored how sportswriters and fans construct their respective narratives and how to design interfaces to better support their practices. We first collected design requirements by observing a sportswriter, analyzing basketball recaps, and characterizing fans’ comments. We then proposed two exploratory prototypes, GameViews-Writers and GameViews-Fans. We conducted two user studies for the two prototypes, respectively, aiming to further understand how sportswriters and fans construct their narratives using the proposed prototypes. Lessons learned from the two user studies resulted in a list of future research directions.
