À Table! Improving Temporal Navigation in Soccer Ranking Tables

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Figure 1. (a) DRAG-CELL and (b) VIZ-RANK, two novel temporal navigation techniques for ranking tables. DRAG-CELL is a direct manipulation technique to browse values over time by dragging them; VIZ-RANK uses transient visualization (line chart) to show the values of cells over time. For both techniques, the temporal slider on the top provides feedback on the current temporal navigation.

ABSTRACT
This article introduces À Table!, an enhanced soccer ranking table providing temporal navigation by combining two novel interaction techniques. Ranking tables order soccer teams represented as rows, according to values of columns containing attributes e.g., accumulated points, or number of scored goals. Because they represent a snapshot of a championship at a time $t$, tables are regularly updated with new results. Such updates usually change the rows order, which makes the tracking of a specified team over time difficult. We observed that the tables available on the web do not support tracking such changes very well, are generally hard to read, and lack interactions. This contrasts with the extensive use of comments on temporal trends found in soccer analysts articles. To better support such analyzes, the two interactive techniques presented allow exploration of time, and are designed to preserve users’ flow: DRAG-CELL is based on direct manipulation of values to browse ranks; VIZ-RANK uses a transient line chart of team ranks to visually explore a championship. An on-line evaluation with 143 participants shows that each technique efficiently supports a set of important temporal tasks not supported by current ranking tables. This paves the way for introducing efficient advanced visual exploration techniques to millions of soccer enthusiasts who use tables everyday.

Author Keywords
Ranking Tables; Soccer; Temporal Navigation; Visualization

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION
Every day, millions of soccer enthusiasts study web sites, newspapers, or other media to learn about their favorite team’s current ranking and how it compares historically. One way to present this information is to use ranking tables. Soccer ranking tables show results for a given championship, at a given day. Rows are teams, and columns are statistics. Column types include, for example: the total points per season, number of wins, draws, and lost games. Tables are updated once a round of games is over, and can become quite large. Assuming a championship with 20 teams, a table will be updated 38 times since each team plays against each other twice.

We conducted an empirical study of 51 articles (weekly and monthly summaries of soccer championships) from major soccer websites, and collected 44 pseudo-interactive soccer tables to investigate how they support temporal tasks. Our first observation was that ranking tables are not designed for comparison, despite the need for analysts and the existence...
of guidelines [21, 15]. Furthermore, 77.3% of tables do not implement column sorting, and 73% of them do not provide any aid for temporal navigation although it may be useful for interactive exploration [15, 9]. Finally, we did not observe any use of visualization, however it provides compact representation for multidimensional data [15, 9] and displays trends over long time periods with line charts [13, 17].

We present À Table!, an enhanced ranking table combining two novel temporal navigation techniques. DRAG-CELL is a direct manipulation technique to browse values over time by dragging them into the Value domain; VIZ-RANK uses a line chart to show the values of cells over time, in the Time domain. Both techniques follow Bederson [4] principles to preserve users’ flow, to focus on tasks and prevent interruptions.

We conducted an on-line evaluation to assess how standard interactions with ranking tables (sorting and changing time with a slider), along with the two novel techniques, DRAG-CELL and VIZ-RANK, can be effective for temporal tasks. Our evaluation shows that the novel techniques efficiently support temporal tasks, which are currently not supported by ranking tables. We discuss the design implications of our improvements and give some scenarios to apply À Table! to other domains of application.

The contributions of this paper are as follows:
1. A Domain description and task analysis for temporal navigation techniques.
2. Two new techniques for temporal navigation in ranking tables, one in the value domain (DRAG-CELL) and one in the time domain (VIZ-RANK).
3. A crowdsourced evaluation of the two techniques along with standard navigation techniques; we then discuss which technique is well suited to which task according to the results and present the main takeaways from the experiment.

Such results provide a framework for further experiments with temporal tasks, and the design of novel navigation techniques in both the Value domain and the Time domain. Numerous application areas where ranking tables are important would benefit from these results.

### BACKGROUND AND RELATED WORK

Soccer ranking tables (Figure 2) are standard ranking tables, i.e. tabular data vertically ordered according to values in one column. Ranking tables have been extensively explored using summarization, interaction and visualization techniques. As far as we know, temporal exploration in tables has never been investigated in a comprehensive way.

A rank is an ordering technique taking as input a set of items \( S \) (e.g., teams) and provides a permutation of these items according to one dimension (e.g., points, goals scored). A rank is a function \( \text{RANK} : S \rightarrow 0, ..., |S| - 1 \), that generates up to \(|S|! \) permutations, i.e. the number of ways the items in the set can be uniquely ordered [11]. Ranks apply to dimensions (columns) \( D \), \( |D| > 0 \). Finally, a rank can be applied to temporal values, where \( t \in T \), with \( T \) a set of discrete events (e.g., games in a championship). \( S_{d_t} \) is the ranking table, which is a snapshot of a championship, ranked according to a dimension \( d_t \) at a time \( t_j \).

A soccer ranking table usually has the following properties: \(|S| = 20 \) teams; \(|D| = 10 \) dimensions; \(|T| = (|S| - 1) \times 2\), i.e. \(|T| = 38 \) games; \( 0 \leq t \leq 38 \). An important property of permutations in soccer championships is that the higher \( t \) is, the less the teams’ permutation amplitude is important because teams tend to have high points difference.

Ranking tables display tabular data and their visual design normally obey to guidelines. Tufte [21] suggests that minor visual improvements, such as vertical alignment of characters and row coloring with zebra patterns, enable comparison tasks and reduce errors. Interacting with the rank order help users perform some tasks (e.g., finding maximum or minimum values) faster, without scanning all the rows. Many software packages, such as spreadsheets, implement ranking interactions. They also provide formulas to summarize rows for more compact representations with Pivot tables [23] by computing counts or totals. The same principles can be applied to columns with statistics such as averages of multiple columns or min/max values to provide other ranking mechanisms [15].

Summarization of tables is an important challenge because rankings are often longer than the screen. Visualization techniques can provide compact representation of cells. Table-Lens [15] represents tables using Focus+Context principles, collapsing rows to their minimum size or up to a pixel. This enables representing large tables on one screen as long as the number of rows is less or equal than the number of pixels. However, one row is always expanded as a focus and the

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Figure 2. Illustrative example of a “complete” table at time \( t \), featuring the most frequent designs and embedded visualizations. Pts: number of points; W, D, L: number of Wins, Draws, Losses; Ho, Aw: number of points at Home and Away; GF, GA, GD: Goals For (scored), Against (conceded), Difference (GF-GA).
content of the cells is visible. LineUp [9] also uses nested compact visualizations in tables, but for headers showing the distribution of values contained in the rows beneath.

Ranking also plays an important role in discovery, particularly when tables are represented as a grid layout where visual variables such as color encode values. It results in heatmap-like representations [20], and ranking becomes the primary interaction for finding patterns [16]. Such tables may become very large and require space transformation techniques, such as zooming or space folding techniques [8] to bring rows and columns back together for comparison.

Visualization techniques to display ranks are mainly inspired by line charts [13], and are also called bump charts because of the visual effect that permutations provide. Slope Graph [21] plots items’ values on two vertical axis—one for each time $t_1$ and $t_2$—and connects similar items from one axis to another with a line. The slope of the line is a visual cue that conveys the importance of the items’ value change. However, some empty space may appear within the chart and elements may overlap. Several recent attempts produced compact charts reducing the amount of space and overlapping, while handling scalability. RankExplorer [17] shows items ranking as a flow, with glyphs wherever two items swap their ranks, or when an item has a particular increase in rank. Generally, visualization techniques are low-dimensional projections of data, that do not keep the original multidimensional flavor and interactivity of tables. They may also break users’ flow [4] because tabular layouts are too different from line charts, which require a cognitive overhead for users to connect both.

In summary, existing table improvements tackle the challenge of better sorting, summarizing, and visualizing tables. These techniques are usually not trivial for a non-expert, which may explain why we did not find any in our empirical study. Another reason might be that techniques are not specifically tailored for temporal navigation, as time is usually a tricky dimension that requires specific attention.

**EMPIRICAL STUDY OF SOCCER RANKING TABLES**

We conducted an empirical study to better understand current soccer ranking tables design practices. Over the 44 tables we collected, we observed that temporal navigation is rarely supported, unless the table uses non-dynamic drop-down lists.

We also investigated the use of time in soccer newspapers by collecting 51 articles. We realized that they constantly refer to temporal trends or team performances during a time period, that current table designs do not support well.

**Time in Soccer Articles**

We collected and analyzed 51 soccer articles, mainly from two highly influential and visited websites: L’equipe $^1$ (70%) weekly summaries for the entire 2012/2013 Ligue 1 Championship in France; and premierleague.com $^2$ (20%) monthly summaries of the 2012/2013 Premier League Championship in the UK. This was completed with articles from Yahoo sports, Wikipedia and other soccer websites (10%). The articles we collected outlined main events of the week or month, and illustrated them with statistics.

Out of the articles, we extracted up to 33 different tasks the journalists had to perform to write these summaries. Then, we grouped similar tasks into generic categories. For example, both tasks “What is the number of points of Paris SG at week 17?” and “How many goals has Marseille scored until week 5?” are subtasks of the generic category “What is the VALUE of TEAM at $t$?”, where TEAM and $t$ are the two known variables and VALUE the unknown one. This grouping resulted in 18 generic task categories.

We observed that all the tasks categories are temporal. Indeed, even the most basic task, such as “What is the VALUE of TEAM?” implies knowing when to look at the value. When $t$ is not explicitly written, it is implicitly the latest week of the championship. We also observed that the most important column for ranking tables is the number of points of a team, determining its rank in the championship. However, the other dimensions also occur, to improve the summary details and analysis. For example, analysts often report: the number of scored goals or wins for the last $n$ games of a team; the team’s performances at home; or a series of consecutive games with the same result (e.g., 5 losses in a raw).

To structure our analysis, we mapped the categories to the task taxonomy for temporal data by Andrienko et al. [3]. Figure 3 illustrates the mapping and provides examples. They classify

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We collected a series of 44 ranking tables for soccer, from UK to France, Brazil and US. We also conducted an interview with a soccer analyst in charge of another team, at different times. From a technical perspective, standard widgets are implemented in every GUI—such as:

- Drop-down lists to directly jump to a specific time. They cannot be used to dynamically browse a time interval but are very efficient to select a particular time.
- Arrow widgets to jump to previous or next tables, with some shortcuts to the beginning or the end of the championship. They are efficient to navigate sequentially, step by step.
- Range slider for 6.8% (3/44), to select the data in \([t_i, t_j]\) and compute the cell values between these two times.
- Slider for 2.3% (one table) to support temporal navigation, similarly to a seeking bar to scrub videos.

The results from our study highlight the lack of temporal navigation mechanisms, and only one table featured a slider which would be recommended as an efficient way to explore such a quantitative data space [19]. We are not able to give any explanation. From a technical perspective, standard widgets are implemented in <HTML> and the data to compute ranking tables are relatively small and freely available. From a user perspective, we showed a dynamic slider to our soccer expert and he found it of great value, wondering himself why he does not provide one on his website.

**IMPROVING TEMPORAL NAVIGATION**

A Table! is an advanced ranking table that includes current ranking table practices (Figure 4), with two novel techniques for temporal navigation: DRAG-CELL is based on direct manipulation of values to browse ranks; VIZ-RANK uses a transient visualization of team ranks (line chart) to explore a championship. Those techniques aim at improving the support of temporal tasks we introduced in Figure 3.

**Features from Current Ranking Tables**

A Table! is a ranking table, along with the following features:

- **Temporal Slider** to give both an overview of the championship, and to provide a continuous temporal navigation.
Figure 4. A `Table`! integration into a web page for on-line evaluation. The interactive table along with the temporal slider is on the left; the quiz, the high scores and navigable animated GIFS as explanations on the right.

Figure 5. **DRAG-CELL**: (a) dragging up and down the value of a cell (in this case, Points of Team Lyon) makes this value change (b) for the set of values it can have, and colored arrows indicate how teams would behave if the drag was released (green to red arrows). (c-d) Releasing the drag animates the rows to their new position.

The slider is also synchronized with the two new interaction techniques we describe below to convey visual feedback.

- **Multiple teams selection** by clicking on team names to select and highlight their row, to facilitate their tracking over time.
- **Column sorting** by clicking on the table’s headers to apply the rank function over a specific dimension.

**Design Philosophy for the Novel Techniques**

We designed **DRAG-CELL** and **VIZ-RANK** with the challenge of preserving users’ flow. We followed Bederson [4] principles by supporting both novice and experts with the same display. While tabular display remains the default view, novel techniques are activated with specific mouse interactions and new representations are animated to prevent users’ interruptions. User is always in control with incremental actions and a visual feedback to constantly show what he is doing.

Because the design space for novel techniques is important, we decided to focus on two techniques which support specific temporal tasks that ranking tables or standard widgets do not currently support: **DRAG-CELL** lets the user interact in the *value domain* and **VIZ-RANK** in the *time domain*.

**Novel Technique 1: Direct Manipulation of Values**

From the task analysis, we observed that the expert estimated as important several inverse tasks which were not frequent in journalist articles. Inverse tasks are challenging to perform using standard tables and it may explain why journalists avoid these tasks. We designed **DRAG-CELL** to make easier to perform these difficult tasks by interacting with cell values directly (e.g., the number of points of a team): the user manipulates the *value domain* instead of the *time domain*, unlike standard navigation techniques such as a temporal slider. Typically, **DRAG-CELL** allows users to quickly find if...
A visual feedback displays a vertical bar at the current mouse position to enable comparison. The team associated to the cell the user clicked on is highlighted.

6. **End:** When clicking on the chart, it is animated back to its table form with \( t \) corresponding to the click \( x \)-coordinate.

**Novel Technique 2: Line Charts as Transient Objects**

**VIZ-RANK** displays a temporary or transient line chart when a user clicks on a cell (Figure 7). This line chart displays the teams’ ranks over the whole championship. The user can click on one point on the chart and \( t \) is set according to the corresponding value. The user’s flow is as follows:

1. **Start:** \( \text{VIZ-RANK} \) is activated by a mouse click on a cell.
2. Then, an animated staged transition [10] transforms the table into a time-line format by successive widening of columns and rows (Figure 6).
3. A line chart is displayed with the X-axis encoding the whole championship time range and the Y-axis the dimension of the cell the user clicked on. Each team line is encoded with Semantically-Resonant Colors [12] that matches teams’ logo (which is also displayed at the end of the lines).
4. The line chart displays by default the ranks, but the Y-axis can also encode the absolute values (Figure 7).
5. A visual feedback displays a vertical bar at the current mouse position to enable comparison. The team associated to the cell the user clicked on is highlighted.

**Figure 7. The two available line chart types: Rank (left) or Value (right). A click on a team’s name or logo on the right selects the team.**

The staged transitions are similar to the ones from the table to the line chart, but in reverse order.

**Crowdsourced Evaluation**

We conducted an evaluation to assess how standard interactions, along with \( \text{DRAG-CELL} \) and \( \text{VIZ-RANK} \), can be effective for temporal tasks. We also expect to identify which task categories discriminate the techniques.

**Methodology**

We released \( \text{A Table!} \) on the web during a 3-week period, for a crowdsourced evaluation. **Crowdsourcing** is the use of an unknown public to perform simple tasks [14]. Participants (workers) are usually recruited through online markets (e. g., Amazon’s Mechanical Turk) and paid to obtain results of quality. We crowdsourced the evaluation because the target user is specific (soccer enthusiast with interest in statistics) and to keep unaltered their environment (they usually browse specialized websites) without paying them. We also picked up this evaluation method because existing tables do not support dynamic temporal navigation and have very inconsistent designs, thus a traditional lab experiment with a baseline comparison would not be appropriate.

We evaluated participants’ performance using a quiz (Figure 4, top right). We designed the quiz’s questions based on the extracted tasks for soccer analysis (similar as the examples in Table 3). We also displayed the quiz high scores as an incentive to engage visitors.

**Implementation**

\( \text{A Table!} \) is implemented using JavaScript and \( D3 \) [5] to run in any modern web browser. The web page is available in English and French at [https://github.com/charlesperin/atable](https://github.com/charlesperin/atable). We implemented the table and the temporal slider on the left; the quiz and the high scores on the right (Figure 4).
We also added a tutorial as instructions for the novel techniques on the bottom right, using a slide-show of animated GIFs. A help button at the bottom opened a help page on how to use the table. The experimental setting is available at http://charles.perin.free.fr/atable. We collected feedback from participants with an on-line questionnaire, reached either by clicking on a feedback button or once the quiz is completed. We used the data from the French Ligue 1 2012/2013 championship.

**Hypotheses**

Our hypotheses for the experiment are as follows:

- **H1**: side tutorials will help users to activate and learn the novel techniques, even without visual cues or affordances on the table.
- **H2**: the temporal slider will be faster for elementary direct lookup/comparison because these tasks only require changing t and browsing the table.
- **H3**: **DRAG-CELL** will be the fastest for elementary inverse lookup/comparison tasks, tasks it was designed for.
- **H4**: **VIZ-RANK** will be errorless for synoptic tasks because it expresses best the temporal evolution of values over the whole time span.
- **H5**: **VIZ-RANK** will be slower for all tasks because the mental representation of the teams for users changes.

**Tasks**

Participants performed tasks issued from each category (Figure 3) using our previously set of 33 tasks. We equally distributed elementary and synoptic tasks. Task variables were randomly generated with some constraints to avoid trivial tasks where the participant’s knowledge of the data would be enough to answer. Participants had to answer 36 questions correctly to complete the quiz.

**Participants**

We recruited participants by advertising the web page URL using social networks, mailing lists and soccer forums, to select appropriate participants interested in soccer and statistics.

**Incentive Impact:** after two weeks, among the 141 visitors who resulted in 242 tasks performed, only **one** fully completed the quiz and answered the questionnaire. We observed the following recurring pattern: most visitors interacted with the table, answered a few questions and then dropped out without finishing the quiz. To encourage visitors to answer more questions and eventually complete the quiz, as an incentive we advertised free cinema tickets to participants with the highest scores. This immediately resulted in a stronger engagement from the participants.

**Demography:** we extracted the following informations from Google Analytics: most of the visitors were from France (60.5%), then United States (17.4%), United Kingdom (4.9%) and Canada (3%). 53.1% used French and 46.9% English.

**Participation Logs**

We logged all participants’ interactions, such as: column sorting, team highlighting, slider navigation, **DRAG-CELL** and **VIZ-RANK** interactions. We recorded the following values for each quiz answer: quiz session, question number, id, and category; time to perform the task; participant’s answer; correct answer; associated interactions ids.

**Results**

Over a 3-week period, we registered 1292 visits and 648 visitors performed at least one task. We discarded the data for participants who performed less than 10 tasks and the 239 answers longer than 120 seconds. 143 performed more than 10 tasks (G1), 62 participants completed the quiz (G2) and 34 filled the questionnaire. Only participants who completed the quiz filled the questionnaire. This results in 6693 tasks performed and 185 636 interaction logs.

**Quantitative results:** participants used **VIZ-RANK** for 31% of their answers, **DRAG-CELL** for 9%, and exclusively the other features for 60%. We performed the quantitative analysis using G1 results—the larger dataset—because we did not find any significant difference between G1 and G2. Figure 8 shows the time and error for all task categories according to performed interactions. We grouped the answers from participants using **VIZ-RANK** and other interactions into VR, **DRAG-CELL** and other interactions into DC, and other interactions (exclusively) into O. When both **DRAG-CELL** and **VIZ-RANK** were triggered, we counted the last interaction as the one that led to the answer. We performed Anovas when the data had a normal distribution (we applied a log transform to the measures of time) and when the analysis of variance allowed it (Bartlett’s K-squared). We used a Welsh two-sample t-test (unequal sample size and variance) for pairwise means comparison. We report significant results only in Table 1.

**Interactions:** Figure 9 shows which interactions were performed, for correct and incorrect answers: all the interactions have a higher percentage of use for correct answers than for

![Figure 8. Time and Error for each task category, by performed interactions.](image-url)
Table 1. Significant results for answers based on Drag-Cell (DC), Viz-Rank (VR), and exclusively other interactions (O). We analyzed the Error for all tasks and the Time for correct answers only.

**DISCUSSION**

**Observations from Experiment and Main Findings**

Soccer enthusiasts with heterogeneous backgrounds in Information Visualization discovered and performed A Table! interactions. Our investigation confirms H1, although users rated the interface as difficult to use. We also had to provide an incentive in order to engage participants and make them complete all the tasks.

Some participants commented that it was difficult to discover the interactions. For example, one participant wrote: “I think it has a low discoverability for the graph and the drag in the cell”. Drag-Cell and Viz-Rank are relatively advanced techniques, performed directly on the table, to let users focus on their task. For such techniques, discoverability is a well known problem (as noted by Bederson [4]). We provided a side tutorial for beginners to learn by example. However, the results showed that almost all participants discovered both techniques by exploring the table, without using this side tutorial and they often accidentally triggered the interactions the first time. In fact, both Drag-Cell and Viz-Rank appear to be quite discoverable without specific affordance.

Answers to the questionnaire confirm the interest from soccer enthusiasts for A Table!; 74% of them discovered new information during the quiz. Interestingly, they scored the team selection, the column sorting and the temporal slider as the most useful features. However, none complained that the novel techniques were distracting, or that they were disturbing obstacles to perform the tasks.

**Qualitative Results:** Figure 10 shows the participant’s scores on Likert scales for their background, questions on the interface and more specific questions about A Table! features. The main observation is that participants’ satisfaction with existing ranking tables is low: 91% (31/34) of the participants would like to have access to such an interactive table on their favorite soccer website. Indeed, they estimate it offers better ways to analyze soccer championships (74% of the participants discovered unknown information during the quiz).
For both elementary inverse lookup and comparison, DC has the lowest mean time and is significantly faster than VR and we partially confirm H3. We also note that for inverse lookup tasks, we did not find any significant difference between DC and O because the standard deviation for O was too high, although it was the slowest technique overall. DRAG-CELL was rarely used, but when it was, participants performed tasks faster and with fewer errors. These results confirm that DRAG-CELL is efficient to perform the tasks it was designed for.

For four synoptic tasks (identification definition, identification search, inverse comparison, and relation seeking) VR has significantly less error than O, participants making respectively 3.6, 4.1, 3.1 and 1.3 times less error using Viz-RANK. We did not find any significant difference between DC and VR for these tasks but the mean error is the smallest for VR and we partially confirm H4. We also note that DC has less error than O for the identification definition task.

VR is the slowest for five out of the six tasks for which we were able to analyze time, with VR being almost twice as long as O for several tasks. For half the tasks with significant difference, VR is slower than both DC and O and we partially confirm H5. We explain this result because participants may not be familiar with line charts. However, it is not clear if this is a general issue, if this is in the context of rank visualization or because of the short apparition of the chart.

Participants used Viz-RANK for complex synoptic and relation-seeking tasks that are extremely painful to perform without a dedicated technique. The technique involves fewer errors but requires more time. However, because journalists cannot afford to publish incorrect data, the technique must be accurate, even at the cost of a slight increase in completion time; comparing time between techniques makes sense when the techniques have similar error rates, which is not the case.

The main takeaways from our experiment are as follows:

- **Basic interactions remain essential, fast to operate and easy to learn for basic tasks.** However, some tasks are almost impossible to perform using only these features (up to 82% of error) and advanced interaction techniques are required.
- **Interactive techniques are crucial to explore temporal ranking tables.** The more interactions are used, the more the task is performed correctly (Figure 10).
- **DRAG-CELL is fast and error-less for the tasks it was designed for (inverse tasks) but almost never used for other task categories.**
- **Viz-RANK is accurate and well-suited to synoptic tasks and all tasks can be performed using it.** However, it is slow to operate and requires user’s basic knowledge in Information Visualization.

Finally, both DRAG-CELL (for elementary inverse lookup and comparison) and Viz-RANK (for four out of the five synoptic tasks categories) makes it easier to perform the tasks they were designed for. Moreover, several of these tasks were almost absent from the task analysis from soccer articles but were estimated as highly relevant by the expert. We may expect that by providing such interaction techniques as DRAG-CELL and Viz-RANK, the analysts will be able to perform tasks they can not perform today and therefore enhance the quality of the insights and statistics they can retrieve from the data.

**Applicability Beyond Soccer and Limits**

A Table! is seamlessly applicable to other sport ranking tables showing team statistics. We now describe A Table! applicability to two types of ranking tables from different domains and discuss possible issues and limits.

**Academic Rankings**
Since 2003, the Shanghai University [6] publishes every year an updated Academic Ranking of World Universities. It ranks the top $|S| = 500$ institutions, with $|D| = 6$ dimensions. The main rank is computed on the number of Nobel Price or Fields Medal winners from the institution, among other criteria. Top institutions like Harvard and MIT are respectively ranked first and second, and tracking them over time can be done visually. A Table! would be efficient to browse the top-$k$, $k = 20$ ranks for which permutations are important but mostly remain on the same screen. However, some issues occur for ranks lower than 100 which are not all visible without scrolling and contain ties. Furthermore, it only ranks the top-500 universities every year, meaning that new institutions may appear or disappear over time, making their tracking difficult.

**Sorting Algorithms Execution**

Sorting algorithms, such as quicksort or bubble sort, perform many permutations until they end in a final result. The number of permutations varies according to the size of the dataset $|S|$. The type of permutations varies according to the algorithm itself. Existing works already explored the visualization of execution steps which enable a non-expert to grasp the underlying sorting strategy. A Table! would be useful to inspect executions and to reach a specific execution step or time. Such an investigation of algorithms—or any ordered dynamic process—can be used in a variety of contexts, ranging from educational purpose to algorithms optimization.

**Limits**

Some real-life rankings may not be immediately compatible with current A Table! design. It is already challenging to visualize and interact with rankings with partial ranks, missing data during time intervals, new dimensions, etc. In contrast, tables do justice to such rankings by creating empty rows or additional columns to represent missing data. It may not be optimal but it has the merit of being a consistent representation.

**Design Implications**

Adding novel interactive techniques to legacy techniques, such as ranking tables, implies many design considerations. We only scratched the surface of making them fully effective, and we share some lessons we learned on their discover-ability and learn-ability. Discover-ability is mainly connected to the affordance of the first interaction to start the technique. We did not use any for simplicity, and considered natural to change values by dragging them up and down. Some codes for affordance are already available, such as Bret Victor’s [22] use of dashed lines to show draggable values. Learn-ability can

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http://www.youtube.com/watch?v=m1PS8IR6Td0
be supported in many ways. The tutorial we provided during our experiment was probably not sufficiently contextualized, explaining why most of the participants discarded it. It seems that it was natural for users to click and drag cells as they are their primary interest. They may have acquired this knowledge elsewhere and applied it to A Table! by associativity [2]. Line charts provide visual guides, but require space and time to appear. Exploring hybrid features, such as dragging values with a visual overlay showing upcoming and past values, might be the best of the two worlds but needs more investigation. Still, regular dragging can be left as an expert-feature [4].

CONCLUSION AND FUTURE WORK
This paper presented A Table!, an enhanced ranking table with improved temporal navigation, by combining two novel interaction techniques. Initially, our goal was to better support ranking tables interactivity and representation of time, as the temporal dimension is crucial to understand soccer championships. We designed novel interactions following Bederson [4] principles to preserve user's flow, to focus on tasks and prevent interruption. Our evaluation shows that the techniques efficiently support temporal tasks, currently not supported by ranking tables, while not breaking user flow. This paves the way for efficiently introducing advanced visual exploration techniques to millions of soccer enthusiasts who use tables everyday, as well as other application domains which use ranking tables.

We also thought to design novel navigation techniques to include in A Table!. One of them is using a table cube metaphor, with a transient 3D animation similar as Rolling the Dice [7], to change a time t or a dimension d step-by-step. This type of transition provides a consistent temporal navigation paradigm—adequate with tables which are also squared—and perfectly fits in table boundaries.

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