Designing Information Visualizations for Elite Soccer Children's Different Levels of Comprehension

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ABSTRACT
We describe a study that sought to understand elite soccer children's use of visualizations to learn about, and improve their own sports performance. We specifically investigate how visualizations support the players' data comprehension. In this process, we design and evaluate visualizations based on real data. Finally, we discuss how the players' level of comprehension might depend on factors such as their general literacy and visualization literacy, and the role of visualization in coaching children.

Author Keywords
InfoVis; sports; qualitative study; interviews; children; teenagers.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
We study visualizations for elite soccer children, aiming to help them understand their individual soccer performance in a manner that is difficult for coaches to communicate. We focus on the children's comprehension of the visualizations, and their ability to use them to consider performance improvements.

Our work relates to visualizations in sports, for children, and in coaching. While sports visualizations has been considered in previous work (e.g., [12,13]) and a workshop has been devoted to the topic [22], focus has mainly been on visualizations for coaches, sports analysts, and journalists. The context of our study – coaching children – potentially necessitates alternative solutions compared to these foci. Thus, our work relates to personal [8] and social information visualizations [14], and visualization work that focus on coaching situations (e.g., [5,6,10,11]).

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In contrast to individual sports logging (e.g., RunKeeper, EndoMondo), which bares similarity to the visualized data, the elite soccer children and their coaches work to form a shared understanding of performance objectives and results. The concept of visualization literacy [2] and studies of children's use of visualizations [3,4,7,21] suggests that children are able to read visualizations, although potentially less effectively than adults. Thus, while it is relevant to understand which visualizations children might able to understand, the interplay between the elite soccer children and the adult coaches plays an equally important role in the context we study.

BACKGROUND
We conducted the study in collaboration with the Danish Football Club FC Nordsjælland (in the following FCN) and Eye4talent. Eye4talent develops a smartphone app for soccer players to record and evaluate personal performance data. The app allows people to manually tag performance specific parameters (e.g. passing, repress, finishing area) either live or post-match based on video. After the match, the app shows a tabular overview of the collected data. FCN is currently evaluating the app with their youth teams of elite soccer children (in the following described as players). The players follow an elite program that combines school and training. They are highly motivated to increase their soccer skills, and so spend most of their leisure time with activities related to soccer. For example, they follow diets, watch soccer matches, play soccer video games, and reflect on their previous and upcoming matches. The children have varied backgrounds, belong to different social classes, and live in different regions. They were scouted to FCN based on their soccer talent. Despite their different backgrounds, their talent and motivation is comparable. Thus, we were able to obtain a varied sample of study participants. Based on our qualitative study we contribute a classification of the players' level of data comprehension and discuss the role of visualization in coaching children.

METHOD
We set up a series of inquiries to study how the players were able to understand their performance data and use visualizations (see Figure 2). Throughout the study, we based decisions for next steps on findings that emerged from analysis in the previous step. In conducting the inquiries, we recorded video or audio as appropriate to the form of inquiry. We analyzed the inquiry data using meaning condensation [9] and open coding [19].

(A) Initially, we conducted four interviews to understand the domain, the aim of introducing visualizations, and establish rapport with club management. We interviewed: two players to learn about their background, daily life, etc. and the team coach and talent development chief to understand the aim of using InfoVis in the club. From this, we learned that the coach aimed to direct the players' attention to their own actions in matches (e.g., number of represses). **(B)** Next, we conducted a workshop with the 12 players on the team. During the workshop, the players recorded their own performance data from a match video by using an existing smartphone app. We also collected textual summaries from the players, which they created based on the recorded performance data. From these summaries, we noticed a) players' varied ability to understand and evaluate their own performance, and b) limited analysis support from the existing smartphone app. We chose to focus on three players in our subsequent inquiries who were likely to represent different analysis capabilities. This is a form of theoretical sampling [19]; we specifically looked for study participants that had shown different analysis capabilities. **(C)** We interviewed the three focus players to inquire about their textual summaries and thus increase our understanding of their analysis capabilities. We subsequently performed opinion-categorization [9] of their ability to explain and reflect on their performance. Finally, we categorized their statements in explanations based on a) the tabular overview of the existing app, and b) the match video. **(D)** We designed several visualizations based on findings from the previous interviews

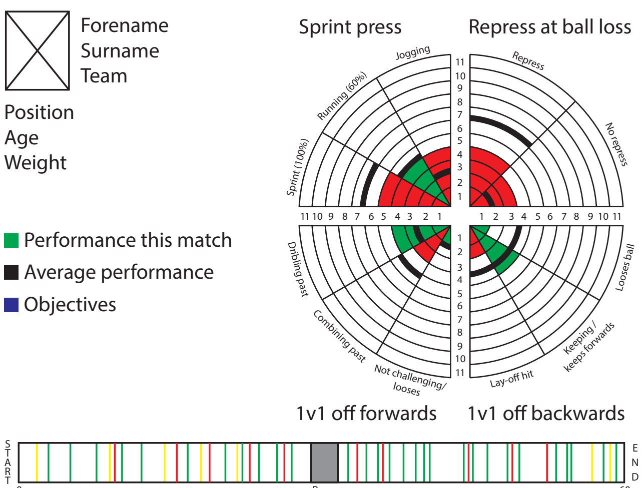

Figure 1: The two paper prototypes were divided in four areas: Upper left, an information area. Lower left, a menu, which provided options for the information shown in the visualizations. Right, a performance parameters area, which showed visualizations of performance parameters prioritized by the player (here showing the Sun visualization). Bottom, a timeline area, which showed actions performed in a match, which also provided a way to link this information to video material. We used green, yellow, and red to encode performance relative to average performance and objectives. Aside from the visualizations shown in the performance parameters area, the prototypes were identical.

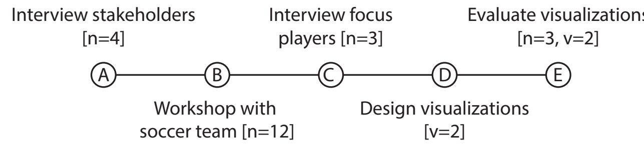

Figure 2: Study process.

(see Figure 1 and supplemental material online[1]). For example, we choose to base the visualizations on radial visualization concepts, since we had learned that the players were familiar with such diagrams from the FIFA video game series. **(E)** We evaluated two of these visualizations with the three focus players (Figure 3), to understand how to improve the players' analysis capabilities with visualizations. We evaluated alternatives to increase the quality and number of evaluation insights [20]. To base the evaluation on real-life data, we conducted the evaluation in the context of a real match. To enable the players to compare their goals before the match to the visualizations afterwards, we asked the three focus players to set personal goals and write them down. To allow the players to compare their goals to their performance, we asked other members of the team to tag the three focus players' performance data. Within a day, we collected the player expectations and recorded the tagged data, built paper-prototype [18] visualizations, and conducted the evaluations. The paper prototype thus visualized the individual players' performance data for a match they played earlier on the day of the evaluation.

By successive steps of inquiries, we aimed to saturate our empirical data about the players' comprehension level. After the evaluation, we analyzed how the players used the visualizations to gain insights and how the visualizations supported their understanding of their performance. We focused on the children's comprehension of the visualizations, and their ability to use them to consider performance improvements. Next, we describe our findings.

FINDINGS

In the following, we present our findings in two separate sections: First, we describe the players' varying capabilities to comprehend their data. Second, we describe how we studied means to support these differences in the study. The primary source of these findings stem from the interviews and evaluations we conducted with the three focus players.

Understanding Different Comprehension Levels

We analyzed the data collected from the initial workshop **(B)**, in which the players used the existing Eye4Talent app. The app shows a simple tabular overview of the performance parameters. By analyzing the data collected at the initial workshop, we identified different levels of comprehension.

At one extreme, the players were only able to explain what they saw. For example, a focus player that did not gain additional knowledge from the visualizations, said: *"I did four*

[1] http://elite-soccer-children.sorenknudsen.com

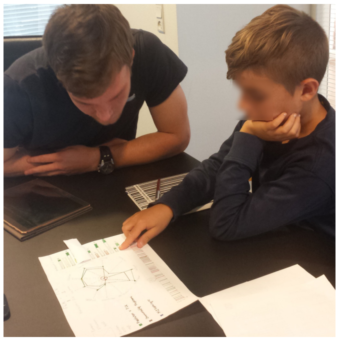

Figure 3: An example situation from evaluating the paper prototypes with individual players.

forward passes, which hit in the feet. One deep, and only one miss" (player 1, subsequently written p1). When asked how he might improve his performance, he replied: *"there's always room for improvement…[but,] I don't really know how"* (p1). At the other extreme, the players were able to explain, interpret, and evaluate the perceived visualizations, and thus discuss potential changes in behavior, which might result in performance improvements. For example, a focus player described data about his performance with improvement proposals: *"I can see it in the numbers, I don't have any loss of [ball] possession, because I am good at keeping the opponent away from me"* (p3). When asked how to improve his performance, he replied: *"I need to keep training my core, because it gives me a physical advantage… also I need to be better at orientation, in order to have a better overview of where my opponent is located"* (p3). Naturally, we observed other players between these two extremes. These for example, interpreted and explained data, but did not suggest improvements.

From the workshop data **(B)**, we understood the varying levels of comprehension. We classify three such levels: First, players that only provide data explanations from visualizations, are classified at comprehension level 1 (p1). Second, players that also provide explanations and interpretations of data are classified at comprehension level 2. Finally, players that consider potential behavior changes to improve their performance, are classified at comprehension level 3 (p3). This classification naturally serves to consider how we might support the various levels, to allow all to gain comprehension. Thus, we became interested in supporting these different levels, to help all players comprehend their own data better.

Supporting different comprehension levels

By evaluating the visualizations with the focus players **(E)**, we studied how visualizations enhanced the players' ability to understand data, and increase their comprehension level.

We observed that the paper prototype helped the player that previously had showed level 2 abilities in evaluating his performance and contextualize it, in relation to previous and coming matches. For example, he structured his actions by color: *"I can see that I have a surprising high amount of red actions in the end of the match. This is because I am getting tired. I should have played more non-risky passes"* (p2), clearly considering how he might change behavior. Thus, we believe the improved visualizations helped him understand his performance data. In contrast, the other players received only marginal benefits from the paper prototype.

The player at level 1 only slightly increased his understanding of the data. This might stem from confusion caused by the visualization, and the player's inability to integrate the visualizations with his memory of the match. The player at level 3 had the best understanding of the match, and had few problems understanding the visualizations. However, he obtained few of his insights from the visualizations, and used most of the evaluation to draw connections between the visualizations and his memory of the match. His insights and his ability to compare his performance to the match resulted in a marginally enhanced level of data comprehension. Thus, the players' different capabilities seemed to influence the value obtained from the visualizations.

DESIGN IMPLICATIONS

To create better premises for all capabilities, we suggest to design visualizations, with a low complexity of initial visualizations – not unlike the Visual Information-Seeking Mantra [16] and multi-layered interface design [17]. Initially, such a design would have a low complexity, and increase gradually with interaction. In our case, this means that each view should show a collection of data, which summarizes the action points of a match. The players might then be able to explore additional data levels, with increasing complexity and additional possibilities for obtaining new insights.

After evaluating the paper prototype with the players, we observed that the gap between the levels of comprehension significantly rose compared to their previous interpretation of video data. This predictably confirms that the tabular overview offered by the Eye4Talent app provided limited support of the players' analysis needs. We base this consideration on: first, that we noticed the players had problems elaborating on their results during the workshop, and second, that the comprehension level 2 player showed an increased understanding by using the visualizations during the evaluation **(E)**.

Finally, our findings suggest substantial differences in children's abilities in using visualizations within a youth team. Naturally, coaches are expected to assist the players in understanding the visualizations. We believe that a tool for this context should design directly for this situation. Doing so, it might provide tools for annotating visualizations, to support collaboration between players and coaches.

LIMITATIONS AND DISCUSSION

We acknowledge that the latter parts of our study is based on very few participants (one for each identified comprehension level). To learn about differences in comprehension, we carefully selected interview participants, who we anticipated to represent different data comprehension levels. This allowed us to study how children at different levels might benefit from visualizations, and how to best support multiple levels in a visualization. Thus, our deliberate choice of participants built on theoretical sampling as argued by Strauss and Corbin [19]. With this approach, we defined comprehension level, by closely examining the player's verbal expressions of understanding and the insights they gained during interviews. Our notion of comprehension level bears resemblance to

Bertin's reading level [1]. In his work, reading level relates to integrating the data presented in the image. Curcio [3] examined the diversity of childrens' comprehension and introduced the notion of "reading beyond the data" – later described as "moving beyond the data" [4]. Our findings resonate with these descriptions, but also suggest a relation to actionable insights that might lead to changes in behavior.

Additionally, our choice of methodology provides a different angle on this topic, which serves to reinforce their conclusions. Our initial findings suggest to identify the range of visualization literacies within the group of people intended for a visualization design, and thus design for diversity within this group – for example, by designing visualizations for weak visualization readers. Comparing visualization literacy to textual literacy, designers should consider how they might lay out the text, such that both novice and experienced readers obtain valuable insight. Gradually introducing complexity (e.g., [15,16]), might be an answer to this. However, other techniques might be fruitful. For example, in children's books, authors might provide subtle gems for parents. How might we do similar in visualizations?

Finally, we described the need for simple ways to collect real data for use in evaluating early design work, and showed how this might be implemented in a concrete study. Understanding how to collect data for such evaluations seems particularly relevant for personal visualizations researchers, and points to an interesting area for further research. While personal visualizations are not designed specifically to support children or teenagers, we believe that the differences within this group shows relevant issues related to personal visualizations, and that it might provide fertile grounds for studying differences in visualization comprehension and literacy.

CONCLUSION

We contributed a classification of players' level of data comprehension based on visualizations, and described three main levels. We grounded our classification in data collected during design workshops, interviews and evaluations with children who were motivated to improve their sports performance. Finally, we discussed the role of visualization in coaching children, and suggested how we might design for this context.

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