FBP:
Digital vs Tangible Data Visualisation

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TU/e GAMES AND PLAY

Abstract

In this research a product was designed to help beginner players tackle the steep learning curve of an online game called League of Legends. It did so through giving visualisations of a core aspects of the game to take some weight of the beginner's shoulders. These functions were then implemented in both a digital prototype and a physical prototype to explore the differences between the two. This is done as there have been different explorations to tangible data visualisation and data physicalisation however not for a physical product with just visual cues. Because of the game's nature it is impossible to actively explore haptic and tangible of a device and therefore can only give visual and/or audio cues. This could essentially also be done on a digital device, but it is unknown whether and which differences exist between the two. The User Experience Questionnaire, Gameplay Activity Measures questionnaire and an interview were combined in a double evaluation with either the digital or physical prototype to explore differences and search for signs of improvement. In the end multiple future directions were discovered next to minor influences that could impact the effectivity of the design.

Introduction

In computer and video games, especially in competitive computer games, it is known that steep learning curves are a regular struggle for players. This is especially true for beginner players as players need to learn a wide set of skills at the same time. This might make games unenjoyable for starters and they pass on a game that could be meant for them. A device was created to accompany and help beginners to understand some core aspects, lowering the heavy load of information on their shoulders.

The design is created for the game League of Legends [11] as the game provides an accessible API, it has a large player base and the researcher has experience in the game. Because of the API, live data can be extracted from the game and implemented in the prototype to give real-time information and feedback. The large player base helps in finding participants and creating a stronger evaluations.

There are numerous applications, websites and companions that are created to assist players. Varying from tools that help in the pre-game by showing the strongest champions and assets, to analysis after the game to spot weaknesses in the player's play. Especially this post-game analysis is elaborate and used in various tools such as Blitz.gg [3] and Mobalytics [14]. In these examples they highlight strengths and weaknesses in the player's play with more detailed explanations and examples from that game.

What however is interesting is that nearly none of the tools use goal setting in their approach to help the player learn. Blitz.gg does offer a CS goal based on the player's rank but this goal cannot be modified by the player. The personalised post-game analysis does give clear examples on what they could improve on, but does not actively set a goal that the player wants to meet. If he wants to improve he would have to make a mental note himself and pursue this goal.

Another interesting aspect is that the live companion tools, that Blitz and Mobalytics also provide [3,14], can be used during the game, give very limited information whilst playing. Moreover, the information that is given requires a second screen and is displayed in line graphs, making it difficult to quickly interpret during the game.

So, what is lacking in the field of available tools is the ability to set and pursue goals to self-improve, and the ability to learn and adept during the game based on the player's personal gameplay, instead of a purely informational analysis after the game. Therefore the research's focus was directed to creating a real-time personalised data visualisation tool that helps beginner players tackle the steep learning curve of league. This is done through a tangible device to explore a new field of data visualisation and potential advantages it might have towards learning behaviour and League of Legends.

The game

The game for which the prototype is created is League of Legends [11]. To be able to understand the later explained functions and evaluation regarding these functions a short explanation about how the game works and what is meant with the vocabulary is given.

League of Legends is a 5 versus 5 multiplayer online battle arena game. The player enters a set map alongside four teammates and try to destroy the enemy core named 'nexus' before they are able to destroy his own core. Both sides have several turrets and inhibitors defending the base alongside spawning small creatures called 'minions' that fight for the teams. During the match the player becomes stronger by killing enemy minions as they drop gold when the killing blow is given. With gold items can be bought which enhance the different statistics (stats in short), giving an edge over the opponent if done better. The total kill count is visualised in the 'Creep Score' (CS in short). Next to that gold is gained through destroying structures, killing enemy characters, or neutral monsters.

The map has three 'lanes' in which the turrets are positioned and minions attack the enemy. These are labelled 'Top', 'Mid' for middle, and 'Bot' for bottom. At the beginning of the match a lane gets assigned to the player, who will face an enemy there. In the beginning he starts here to gain the most of the minions' gold. This phase is called the 'laning phase'. Afterwards, most of the time it is seen that teams start to group up to either take an objective, a structure or an epic monster, or defend against a winning enemy laner.

The game is extremely versatile as there are over 150 different characters or 'champions' to choose from and go into battle with. Each champion has unique abilities and together with the fact that each of these characters must be played differently when they face a different champion causes that no match to be the same.

Background Research

Tangible data visualisation is a wide field and even though it has been around for a while, it seems that a large part is yet unexplored and unknown [6,20]. It has clear opportunities and advantages over the known digital data visualisation as the user can explore data, models or other information more easily when it is put into a physical form. An example is the research done by Hull and Willett [4]. They explored the role of physical models for the architectural design process and use of data physicalisation, and found that their participants could use the tangible design to easily find mistakes and other ideas.

From a more technical perspective, different research has been conducted to explore how a tangible device can have an influence on the user and its environment. Different directions can be seen here. Truesight [1] was focussed on providing a helping hand in the physical table top game Dungeons & Dragons. Motiis [7] explored creating a link between the digital gaming world that children enjoy with their parents to enable parents to understand the emotional states of their child. Modata [21] explored how a tangible tool could be used to further enhance the gaming experience from a spectator perspective. Have a break [17] focussed on the ambience and room of the gamer and how their device could influence whether the player would continue gaming or not based on his mental state.

There are many more examples, however, one direction seemed unexplored. All these examples have either direct haptic or tangible aspects through which the user can play with the design or that the design influences the ambience of the user. What seemed unexplored was whether a physical data visualisation has any advantages over the digital counterpart. Digital visualisation have been explored in various ways [18], but not in comparison with the physical visualisation. In the quest of creating a live feedback tool for beginner players this dilemma occurs. Whilst the player is actively busy in the game, he does not have the time to fidget or explore any haptic or tangible functions. The device would therefore be limited to visual or audio cues which could be implemented in a similar digital device. Therefore both are created in this research to search for first insights on differences between the two.

Product Design

Community Survey

To explore the current opinion and needs of the player community a survey (Appendix I) was distributed via Facebook groups, Reddit threads and snowball sampling. In the survey players were questioned about their use of existing tools, what types of goals they would like and the way these goals are set. Since the focus of the project is towards newer players, more experienced players are asked to fill in the survey looking back towards their struggles in the lower ranks.

In the end 174 participants filled in the survey, spreading across all skill levels (from under level 30 to Challenger). From the results it is interesting that 160 out of the 174 (92%) players use a form of additional service for information about the game, most of them using multiple types of tools. The live companions however aren't used as broadly as other general informational tools with only 21% compared to for example Champion builds/Itemisation with 83,4%.

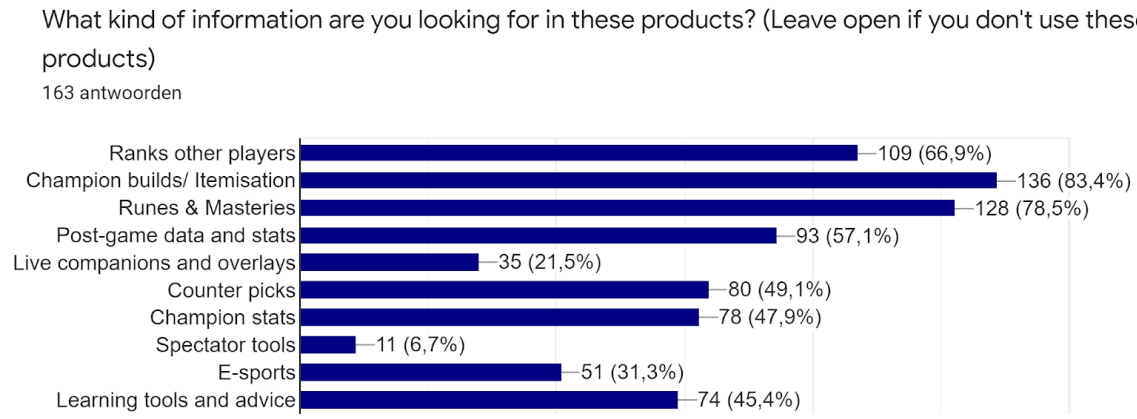

Figure 1.1 Survey graph: What kind of information are you looking for in these products?

In terms of the goal types it is clearly agreed by the various players that creep score per minute is a general and important goal. Effectivity in team fights, vision score and itemisation follow suit, but overall the lowest score was 34,7% for gold spending behaviour, leaving it an optional goal. After analysing the comments given with the answers a few important takeaways come forth: It is noted that players like the idea of live feedback while playing the game than just preparation and analysis. However, some of the aspects that are given are too subjective to create hard goals or might create suboptimal habits for the player's team. And most importantly: The goals should be reachable by the individual and not too dependent on the team.

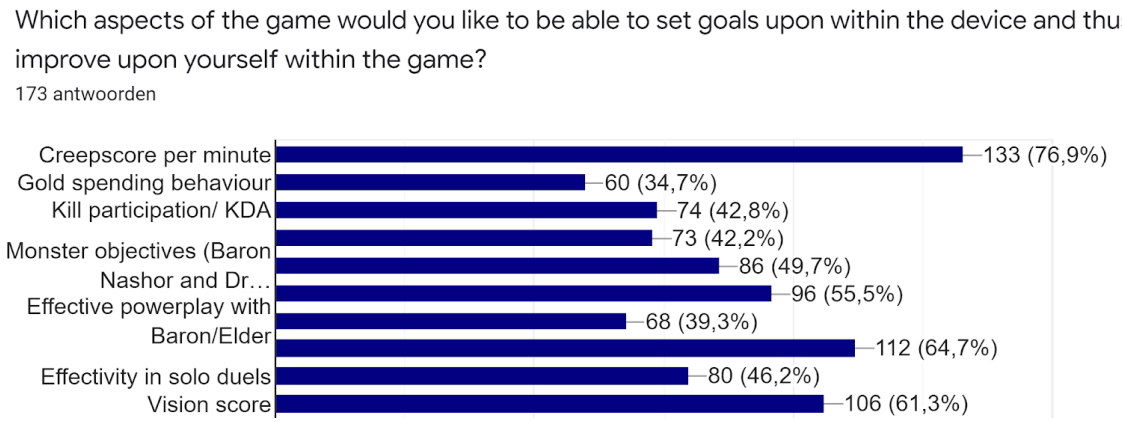

Figure 1.2 Survey graph: Which aspects of the game would you like to be able to set goals upon within the device and thus improve upon yourself within the game?

In terms of goal setting the opinions differ based on selection, however from comments it was noticeable that all opinions come down to having a default goal set for them, but being able to manually influence the goal. If the default goal is a general goal, automatically based on their rank or either of the two depending on the type of goal didn't matter.

Expert interview

With the survey's results an interview was held with an expert in the field. The expert is a performance coach of an E-Sports team from the Belgian League. Above only remains the highest competition, the LEC, showing the level of his team and therefore his expertise within the team. His role in the team is more maintaining the well-being of each player in terms of a mental state, however, he still follows the game on such a level that he is able to talk about the different aspects of the game on a high level. The results from the survey indicated that all aspects of the game might be interesting to include in a product, but needed to be individually reachable to be successful. With this core the interview was held. It was a semi structured interview following the topics of the survey. It started with information about who he is and what he does followed by the type of information and how he would present the challenge and learning goals to the player. From the interview a few aspects came forth:

Many of the given aspects are too dependent on other variable to be implemented in goals during the game. For example vision score makes the player dependent on his ability to roam. If he is pushed in continuously the player lacks this ability and therefore doesn't reach that goal, leaving it outside of his influence. Therefore, any team oriented goal is also left out from the prototype, since the player can't directly influence the choices of his teammates.

With the beginner player in mind it was decided that the product should focus on several aspects: CS/min goal, itemisation recommendations based on the current state of the game and mainly the possible matchups in the game. Since the game currently has 153 champions, it becomes difficult for new players to learn and understand all the different champions and how to play with or against them. If they acquire that knowledge actively through a product rather than having to figure that out themselves helps strongly in

closing that knowledge gap and makes them able to focus on the actual skill and strategy to win the game.

Another main point to take from the interview was the element of feedback combined with the information given during the game. During the game the player does not have time to analyse an action or understand why an item has to be bought. However if the player is not notified elsewhere why he had to buy the item, he does not learn from the advice, which is the main goal of the product. Therefore the combination of giving live personalised data for the game, combined with feedback after the game on what exactly happened and why would strongly help the player develop.

On goal-setting: the expert believes the best way to set a goal would be to have a default goal that would automatically grow with the player, but with the ability to manually alter the goal. He advises against looking to a rank-based goal since they are ill defined due to the many different ways games can play out. He advises heavily against comparing to opponents since an unfortunate highly ranked opponent could outclass the player, while the player is still performing well, which would give him negative feedback.

So summarised: A product would have to focus on specifically matchups combined with a personalised goal on CS/min and itemisation recommendations on the current state of the match. This would then be evaluated through feedback on the decisions that the player made during the match.

Product state - Midterm

With the aspects concluded from the community survey and expert interview a first prototype was created. The focus was going to be a real-time data visualisation device to help beginner players that would focus on CS/min, itemisation, matchups and constructive feedback.

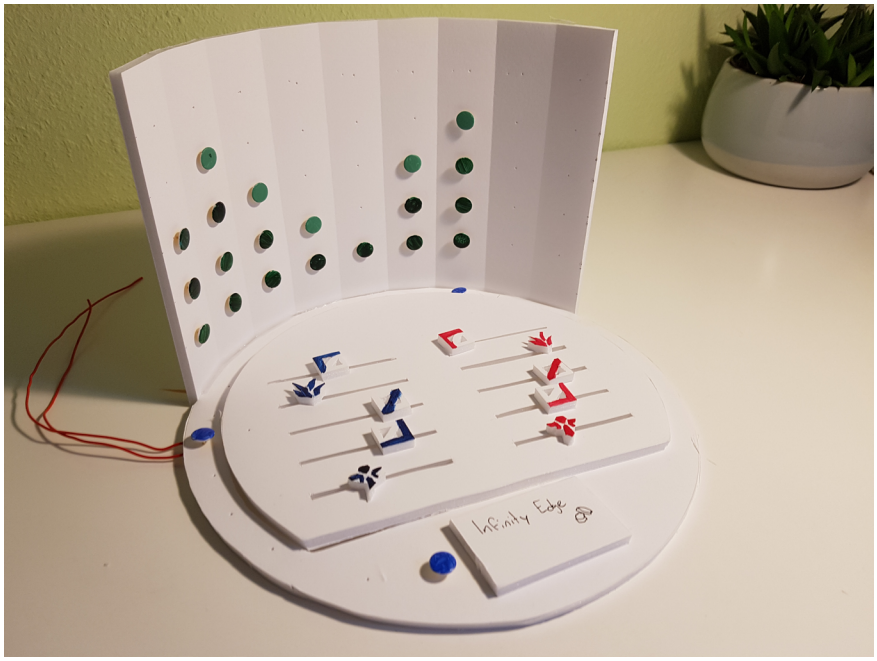

Figure 2 Midterm lo-fi prototype

At the midterm the form and functions of the prototype still needed to be iterated, but it had a form given above. It would have 5 functionalities:

- **Tips:** In the loading screen the player would receive tips on his monitor on how every champion in the game would like to fight and which weaknesses he/she has. This makes the player aware about strengths of his teammates that he can abuse, but also when to engage if an enemy is in a weaker state (shown at 'Final Design').
- **CS/min:** On the back wall of the prototype LED's would start glowing matching the player's CS/min score. The score for every 5 min segment is represented with the different sets of LED's. The middle (third) LED would be the player's personalised goal and every LED above or below would differ in 1.0 CS/min from his goal. In the end a graph would form, giving the player information about when he excelled in his CS and when he is lacking, giving him the information on when he should focus more on killing creeps.
- **Power level:** In the middle of the prototype 10 sliders are placed to represent the champion's power level. The role of the player determines the which slider corresponds with which champion the game. The power level is calculated by an algorithm combining scaling, items and levels to a score. Through this data the player becomes aware of which champions are strong or weak and whether he should or shouldn't fight a certain champion.
- **Itemisation:** On the bottom a small screen visualises the item that the player should build at that point in the game. This keeps the power level of enemies and their type of damage in mind, as well as some other forms of buffs and debuffs.
- **Feedback:** At the end of the game feedback is given on the fights in which the player participated and why the advised items needed to be bought. This functionality is here to applaud the fights that went well, but learn from the mistakes and why a certain item was strong at that time (shown at 'Final Design').

LED's would visualise a flow of data from the PC to the different aspects of the prototype. This is done following the principles of Rich Interaction [8,12]. Frens and Campenhout both focus on the principles of rich interaction and giving more meaning to digital devices. One of these principles is making the complex concept of data graspable. Through letting data 'flow' towards the different functions of the prototype the player is able to 'see' the data, making him aware that the function will be updated when it arrives.

Midterm - A change of direction

At the midterm the product was received quite positively. Four students, that are also League players, praised the advantages from the different functions in the prototype, especially looking back towards their struggles when they were beginners themselves. One major comment however was the following:

"From my point of view it is easier to put the data on your progress in your screen, so you won't have to change viewing points"

"Wouldn't it be easier to just incorporate a screen to show these values on?"

With some iterating and brainstorming about possible interactions or tangible ques the following was concluded: Other forms of cues aren't really a possibility since it becomes too difficult to keep different champions apart from each other if a vibrating motor would be put in a mouse for example. Interactions are similarly not possible since the player lacks time to interact with the prototype, since the main focus still lies on the match. The device could potentially offer functions that would introduce the tangibility before or after the game, but the main intention is giving additional information during the game.

No real tangible aspect could be added to the device without drastically changing the purpose of the device. However, it remains true that the functionalities on the device could essentially be displayed on a second screen next to the screen on which the game is played. This caused a change in direction of the project. The differences between a tangible product and a digital product are known, however it is not known when the focus is solely on data visualisation, with no real interaction between the user and the product besides obtaining the visual data. Therefore the focus of the project changed to more research oriented with the following question:

"Is there a difference in self-improvement, efficiency and/or usability between tangible data visualisation and digital data visualisation?"

Final Design

After the midterm, the feedback that was gathered and the change of direction not much changed in the core functionalities of the design. It was still centred around the personalised information on CS/min, power levels and itemisation, combined with tips beforehand and feedback about the whole match after the match.

The main thing that changed was that a complete second prototype, a digital one, was added for the evaluation and comparison. The digital prototype is displayed on a second display, next to the main display on which the game is played. The digital version resembles the physical prototype as much as possible, with the same functions and visualisations. Therefore the same 'sliders' are used, the green circles to resemble the LED's from the physical prototype and display for the itemisation.

They share the way the tips and feedback is given, since these aspects were intended to be on screen anyway. The aspects that were visualised in the physical prototype are represented in the same manner in the digital one.

The icons on the sliders are extracted from the game. They represent the different lanes and roles. Every player is assigned to any of these roles and is therefore a strong static indicator that could be used in the physical prototype.

The CS was designed around the ideas of Frens and Campenhout [8,12] as the different segments would 'fill up with data' which is shown through lights. As there are no real interactions in the device their principles could not be further used. Ideally different modes would be implemented where the functions would only appear when they are actually active, but since the physical prototype had to completely work, technical limitations stopped this development.

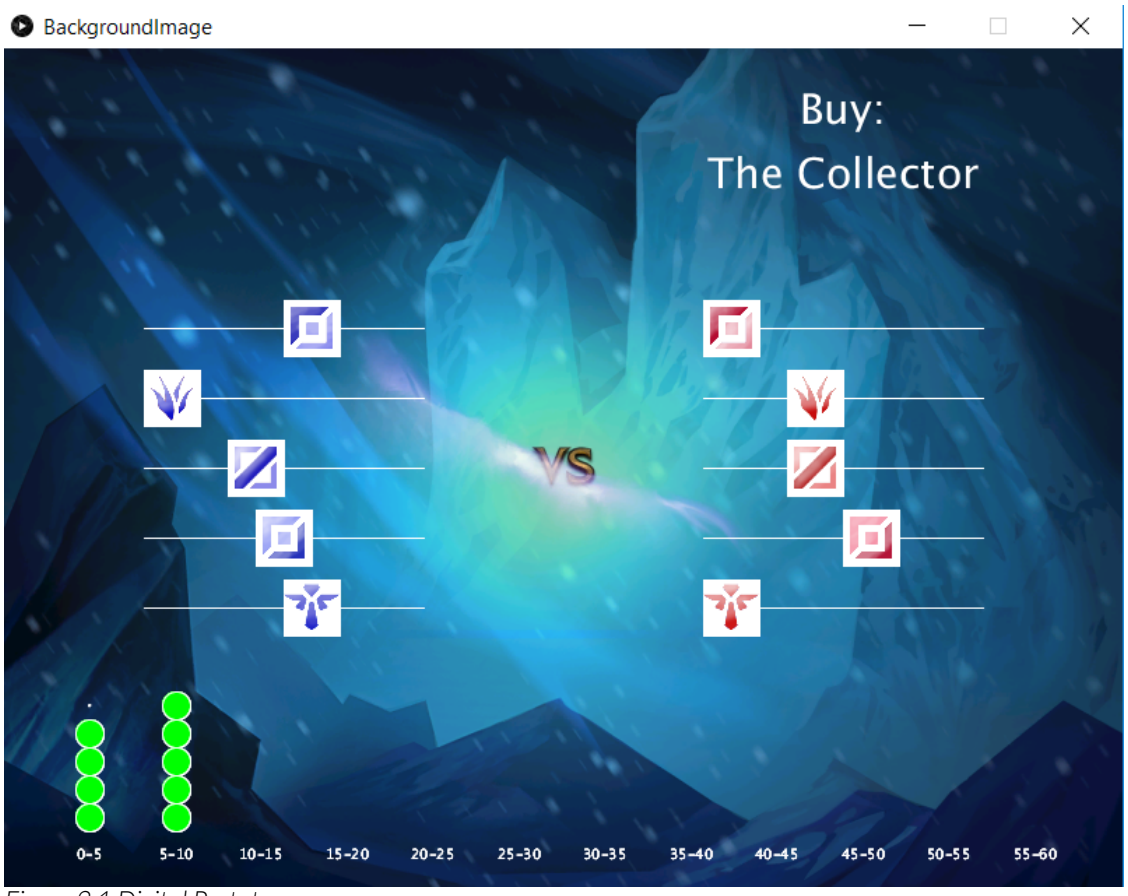

Figure 3.1 Digital Prototype

Figure 3.2 Physical prototype

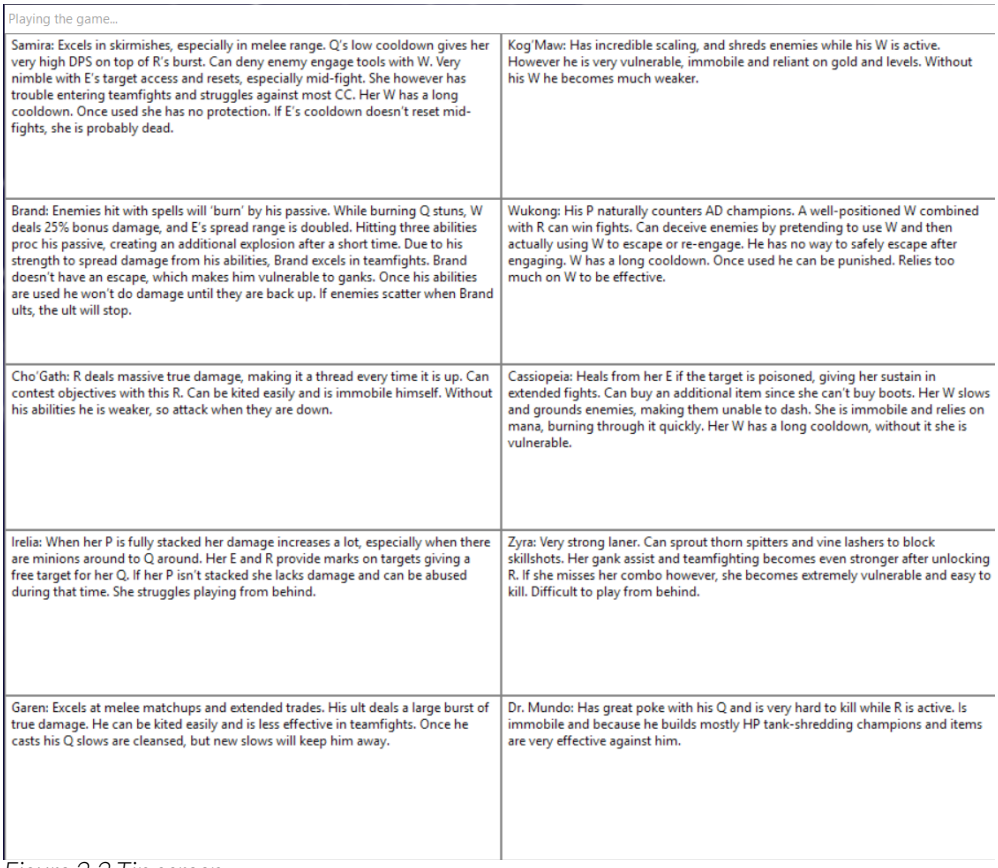

Figure 3.3 Tip screen

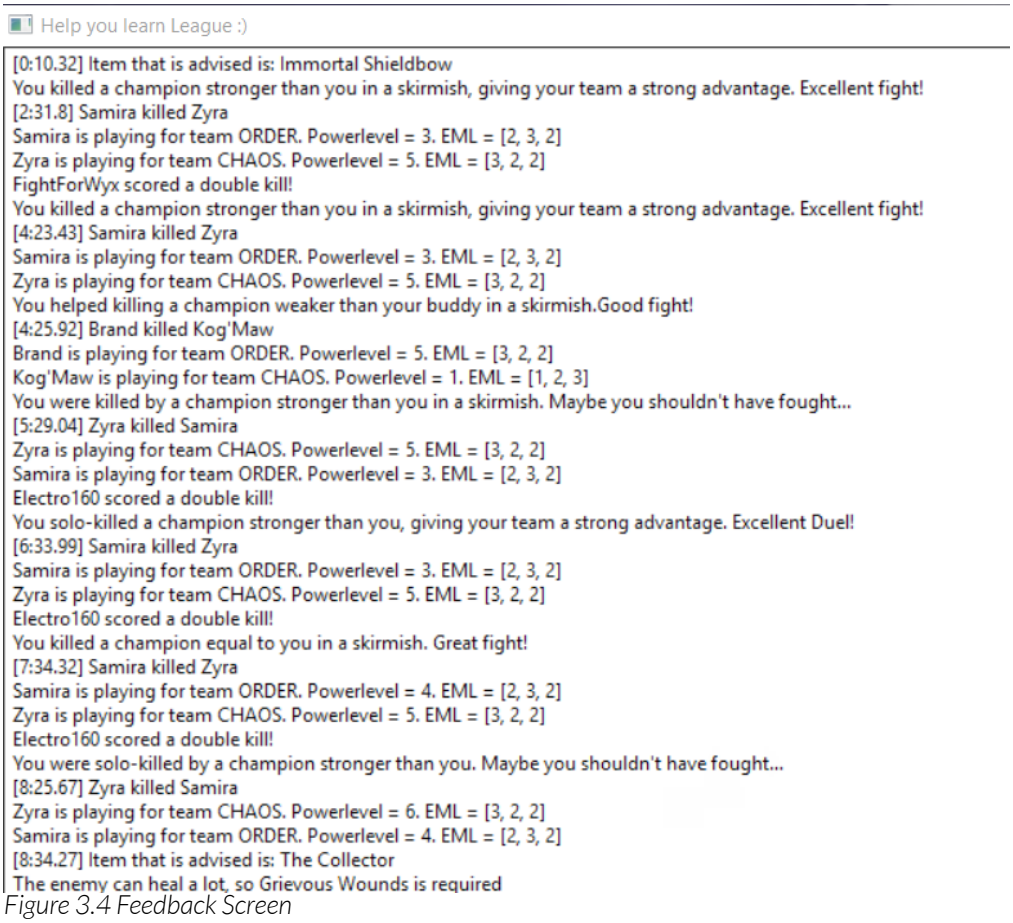

Figure 3.4 Feedback Screen

Evaluation

Procedure

In order to evaluate the difference between the digital data visualisation and the tangible data visualisation the following method was used: Participants were sought through snowball sampling and split into two groups. At first the criteria for the participants was to be under the rank 'Silver' in league to gain less experienced players and beginners as they are the intended target group. However, when only a few players were gathered this criteria was discarded to gain a decent participant number. They were put in the different groups based upon whether they had a second display available to them or not. If they did the evaluation could be perceived online with the digital prototype, which was desirable because of the Covid-19 situation during the project. Therefore one group would play solely with the physical prototype and the other solely with the digital prototype. Every participant has two evaluation sessions. The evaluation session consists of a demographic interview and an explanation about the functionalities of the prototype. Then a match of League of Legends is played which is followed by the standard user experience questionnaire (UEQ)[2]. and gameplay activity measures questionnaire (GAM) [22]. After filling in the questionnaires a short interview is held by the researcher, regarding their experiences in the game and how they perceived the prototype and the information that it gives. The exact evaluation plan is located in the appendix.

In the second session the participant is asked whether he played games between the sessions and whether he took the aspects that he wanted to improve on with him during these games. Then similarly to the first session a match is played followed by the questionnaires and an interview.

There are two sessions in place to try and indicate a difference in improvement. The different components of the GAM questionnaire are compared. The answers to the interview questions are then used to explain the questionnaire results.

The participants are split in groups to refrain from a biased effect if they were to compare the prototypes. A possible thought that might occur when seeing the physical and digital prototype is that one might look like it took more effort to build and therefore the participants are more positive in their to evaluation to that prototype. With presenting only one prototype to them, this effect will be non-existent or more equal since they would have the same feeling towards either prototype.

The participant group contained 13 participants. 6 for the physical prototype and 7 for the digital prototype. Their age ranged from 18 to 28 years old with the mean at 22,3 years. Three participants were female, with the other 10 being male. The type of player differed per participant. Some were beginner players, so a lower level, less games played per week and a more casual approach, others were more competitive and played multiple games per day and some played not as much but had a higher level with which they were content. The level differed between level 18 and ex Platinum 1 players. Frequency of games played went from multiple games per day to a few games per year, however, most played roughly one game every two days.

Evaluation expert

After the evaluations with the players have been completed and analysed, another meeting with the expert, that was interviewed during the design phase, was held to validate the findings that the researcher had brought forward from the evaluations. The interview was held as a form of validation as he is a very experienced player himself being a diamond player, next to his expertise in the coaching perspective he has towards the game.

Data analysis

To compare the digital and physical prototype the following is done:
For every participant the following is compared:

- The UEQ questionnaire
- The different components of GAM questionnaire
- Their experience after two games with the prototype

The interview data is analysed according to the Steps for Qualitative Data Analyses described by Terre-Blanche, Durrheim, and Painter [13]. First, the recorded interviews were transcribed. The researcher printed and read through the interviews numerous times in order to immerse themselves in the data gathered and gain a holistic, in-depth analysis. Then, open coding was used to further break down and organize meaningful instances of data. Words and phrases were highlighted and given codes that were as close to the vocabulary of the interviewee as possible. After, the different codes with the corresponding quotes were cut out and grouped. These themes ultimately exhibited the major findings from the data gathered and the numerous perspectives of the interviewees [10].

The data from the participants is then discussed with the expert to further evaluate and go in-depth about the different topics and future improvements.

Findings

Here the different findings from the evaluation interviews for the different functions are given, followed by the UEQ analysis and GAM analysis. Lastly the expert evaluation is given on both the functions as the digital versus tangible data visualisation. At the beginning of each section the corresponding segment of the coding tree is given from the complete tree given below. After each branch a number is given, which tells how many participants have said something about the branch's topic.

Figure 4.1 Complete open coding tree

Tips

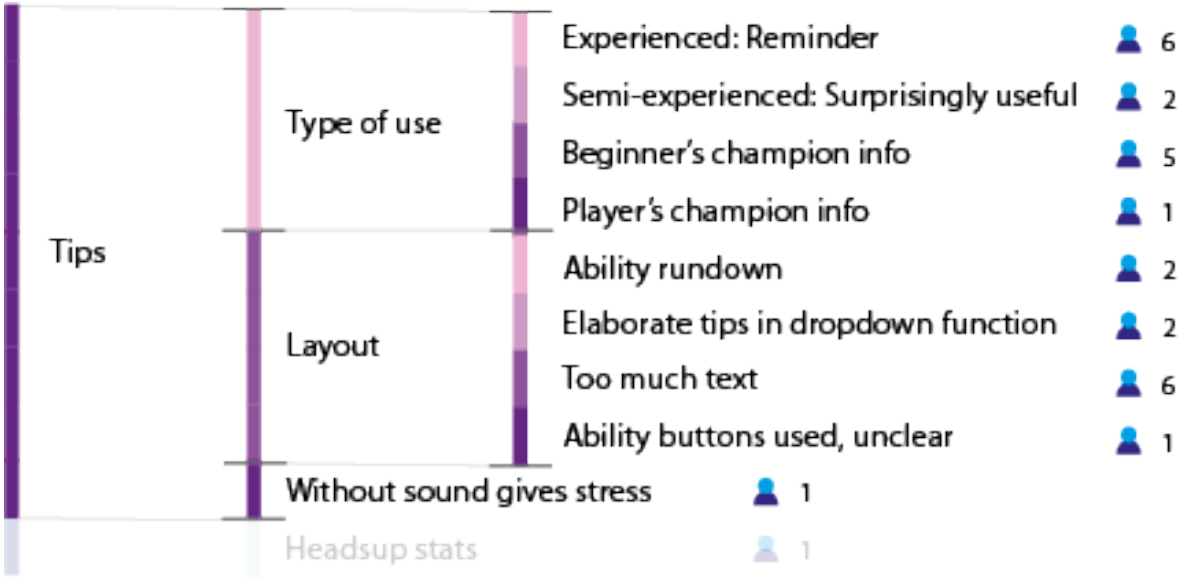

Figure 4.2 Open coding tree: Tips

The tips were for 6 overwhelming as it is too much text to read in the short time window between champion select and the actual game. The tips themselves however were found really useful in several ways. The more experienced player used it as a check to remind themselves of disadvantages and advantages of the different champions. Two players really found some information that they could've thought about themselves, but simply didn't think of it, giving them an edge in gameplay. *P4: 'I could have thought of these tips myself, but simply didn't. Because of the tips I could exploit the opponent's weaknesses'.* Other players really gathered information from the tips about a champion they didn't know about. *P6: 'The tips were very useful. What was told actually happened. The first few times I still fell for it but afterwards I could tackle it because of the tips.'* The tips were also useful for the champion a player was playing himself as to what he should be careful of and where his strengths lie.

A few notes: If the player is playing without sound he/she cannot hear the game start, which makes it a bit stressful to read as it might be that the game already started. Next to that it is seen that in tips the ability buttons Q, W, E and R are used, and a beginner player does not know which ability belongs to which button.

A proposed version to shorten the text and improve readability would be to give a small ability rundown with a few words to describe. An example for Ashe's R would be 'Global stun skillshot'. The more elaborate tips that are described now could then be hidden in a dropdown text when a certain champion is selected to give more information about the playstyle of the champion. By doing this the elaborate information is only given if requested and therefore the readability increases. *P5: 'Now the tips are elaborate combo's in many lines. They are useful however… A dropdown where the tips would be visible on click might be interesting.'* One beginner that was told about this idea said that the elaborate tips could in her eyes be left out as it was simply too much text to read.

CS

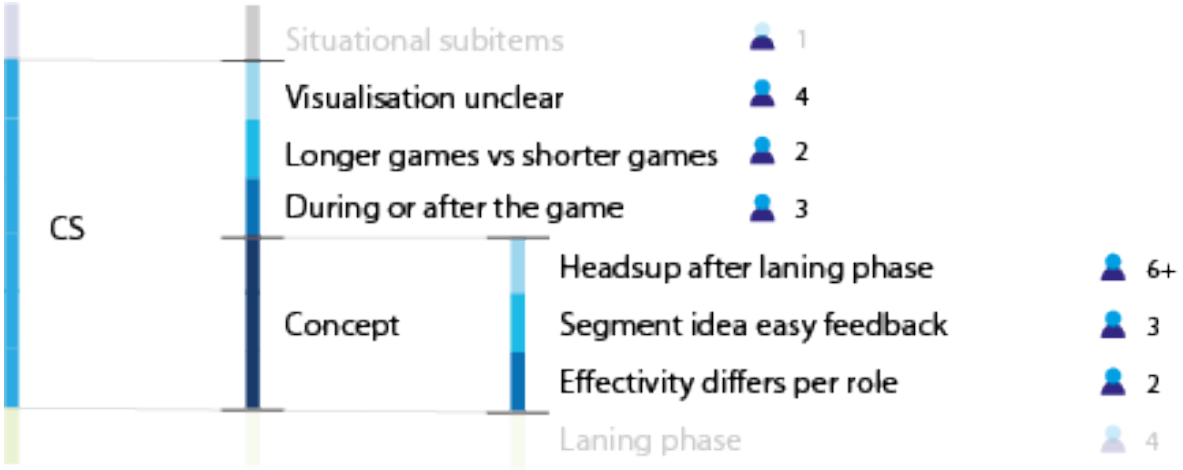

Figure 4.3 Open coding tree: CS

The CS function was nice to have and certainly useful, however the visualization was unclear and therefore difficult to read during the game. After the game it was clearer since the player could take his time and inspect it and the differences are visible then. The same goes for longer games over shorter games, since more data points are present to really create a graph.

The concept was really appreciated and more than half of the players noted that they became aware of sloppy behavior after the laning phase ended. *P10: 'The prototype makes it clear when your CS starts dropping after the first 15 minutes, so you can focus on it in future games'.* It differs between player whether they notice this during the game or after the game, but they did notice it giving them effective visual feedback to take to the next game. *P11: 'During the game it was difficult to read the CS due to time pressure. After the game, when I had time to read it, this information really came forth'.* Normally they wouldn't have known when their CS was falling and have to extensively pay attention in a replay to figure it out.

It is, however, noted by 2 players that CS is not as useful to all roles in the game. A support would of course not CS, but a tank would need less CS to be effective, but an ADC or mid laner needs as much gold as possible making the CS and therefore the tool more useful to them.

Even though they did see the potential, some players simply maxed out the base CS setting, causing them to be unable to really use the function. This however caused them to want to keep it completely filled out all the time, which then resulted in a higher CS than normal.

Power levels

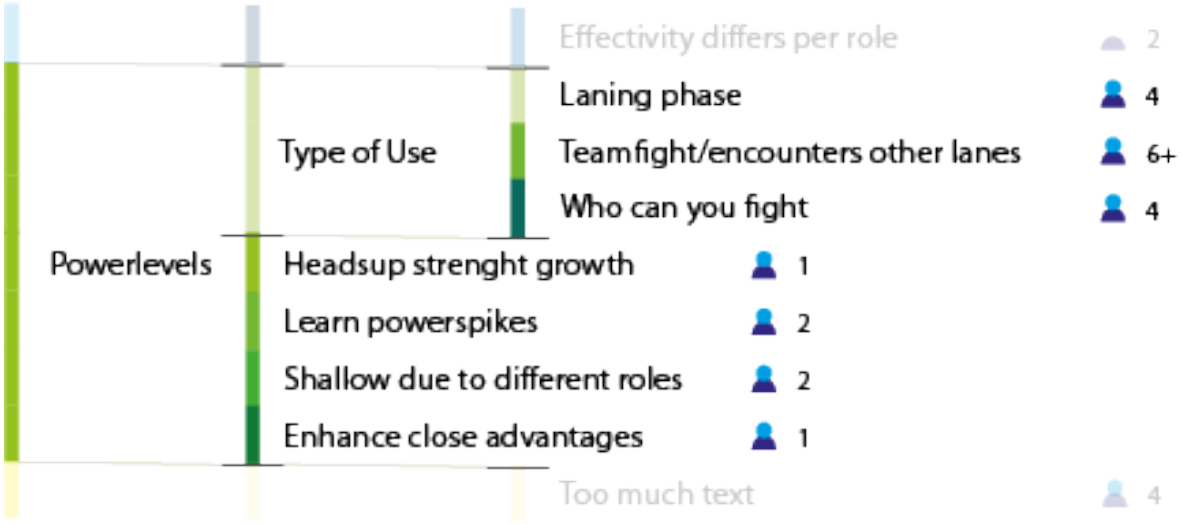

Figure 4.4 Open coding tree: Powerlevels

The power levels were definitely useful to all players. Where and when however differs. 4 found it useful during the laning phase to see whether they were stronger than their opponent and could fight, but thought the use diminishes after the laning phase since the game then becomes too complex. 8 however thought that the use came mostly then to learn about the champions from other lanes as they did not encounter them. This is not necessarily a downside as players can use it to their wishes, but the why is interesting.
It is useful to get a heads-up of power spikes so that the player knows he grew in strength and maybe could pick a fight he previously couldn't. Also goes for the champions a player doesn't know and faces to tell whether they are strong at that moment or not. *P4: 'I noticed I was stronger than the opponent, which then gave me the courage to fight and go in. This is not something I would normally do.'*

Without the prototype the player wouldn't know certain power spikes and make unnecessary mistakes. Basic power can be correlated to bounties, items etc but these champion specific spikes are unclear. *P9: 'The prototype makes you aware of the suprisingly strong champions. Pantheon for example was stronger than I expected, because he didn't really have items. Later when I saw him assassinate someone, the power was justified and I decided to keep my distance.'*

Because of the prototype a player is able to quickly tell who he could fight and who he couldn't. It also shows unclear advantages as he was surprised that the enemy Vi was that strong. He can't tell on what the level is based, but at the same time that doesn't seem necessary. From the power levels he could tell who was the teams win condition and to play around that which is useful information. *P5: 'An unexperienced player I know could win lane but not notice that the enemy midlaner was winning even harder. Getting this knowledge before dying is definitely useful there.'*

On the other side a player thought the power levels were a bit shallow and difficult to follow due to different roles a champion can have. A tank may not have many items, but against an ADC he is still strong. In the laning phase he really did like the idea since it does give value here to know when to fight. He acknowledges that scaling is taken into

account, but thinks that roles are more important later in the game than actual power. *P7: 'In their objective sense they are not strong but against certain champions they are stronger. That could be misleading. A Rammus is strong against most ADC's. It doesn't really matter whether he is ahead or not.'*

General feedback: The clear cases are represented in the prototype, however the close advantages are less clear and these are the ones the player wants to capitalize on since they can win him the game.

Itemisation

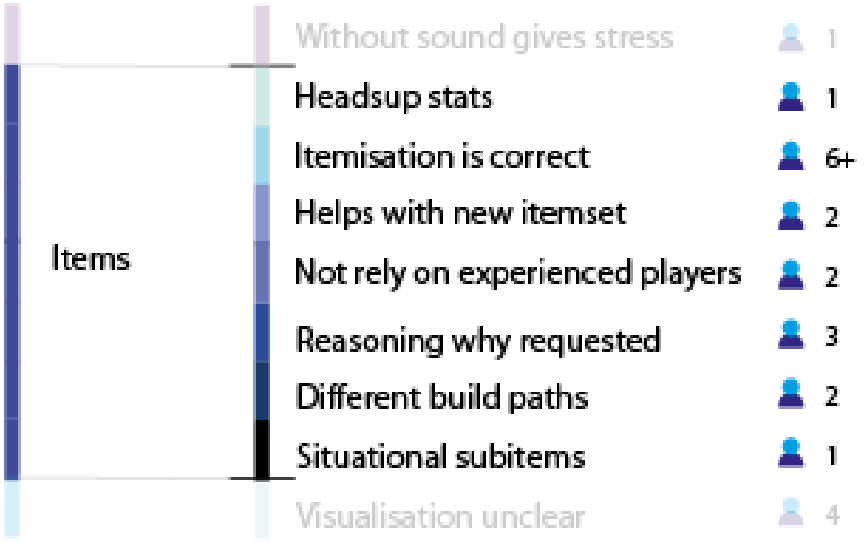

Figure 4.5 Open coding tree: Itemisation

Overall the itemization tool does its job well and the items that are proposed match with what the experienced players would buy themselves. Because of the function the player is able to start with a new champion and learn what the best items are immediately. The function also provided an efficient headsup for certain stats. For example armor if the enemy is AD heavy.

In the new season a brand new set of items was released and because of it the prototype really helps with learning these new items. This makes it more useful across the different skill levels. In one case a new item was proposed that the experienced player was unfamiliar with. Because of the proposition he tried it and learned to play with this item because of it.

Two beginners noted that they liked having a tool that proposed the best item for them so that they don't have to rely on other experienced players. For beginners it is also an efficient way to learn to build situational items and not always buy the same items. There were a few mentions for further improvement however:

First of all, a reasoning behind the advised items is requested by three participants. This information is given after the game in the feedback, but a short explanation in a few words would already help during the game. Then the player becomes aware what the item does. Why it was advised at that point would be step two, but it is definitely a start.

An addition would be to include different build paths depending on the player's team. Some champions can fulfill multiple roles and this role is determined by both the player and the other champions in the game. An example would be where a champion can go for a tank build if no other tanks are present.

The proposed items are always complete items. These items are clear but in certain situations sub items are needed since they give an unique effect, but the whole item is not yet needed such as predator boots or QSS.

Feedback

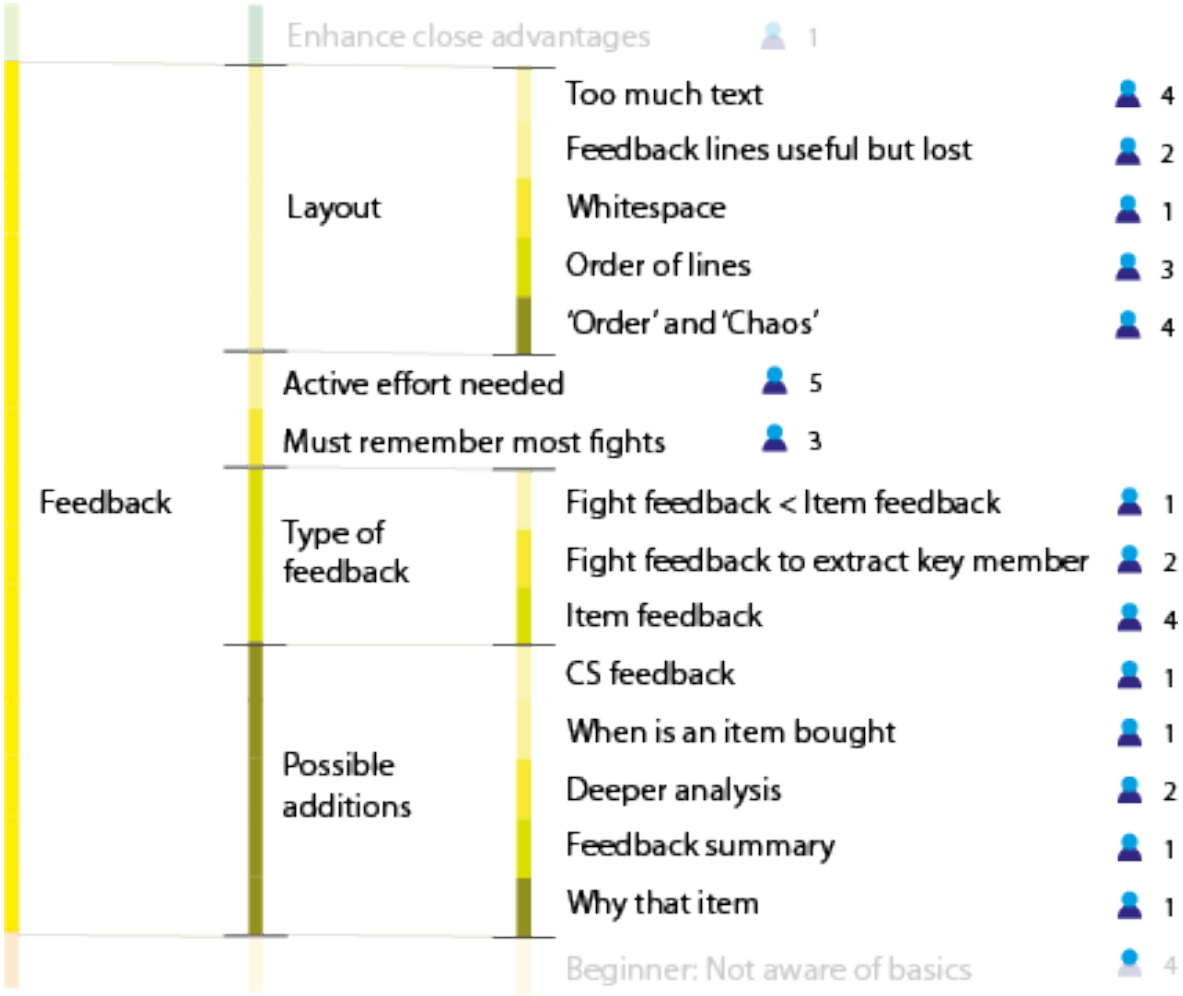

Figure 4.6 Open coding tree: Feedback

The feedback is a lot of text and therefore difficult to read and chaotic. An active effort is needed to go into the information to learn something from it. *P10: ' If you want to invest time than you can definitely gather some useful information but you do need a good thirthy minutes to do so.'* Together with a replay the feedback really strives since it does provide timestamps, but without it most fights need to be remembered to gain something from it. Without the fight feedback becomes useless without a replay.

The main thing that should be improved is the layout and visualization of the feedback. Once seen the feedback that is written down is useful, however lost in the many lines of text. A bug caused some whitespaces to appear during one of the evaluations, making

the feedback lines to come forth more. Next to that the order of lines is wrong giving the powerlevels and feedback before the actual event which they are explaining, making it difficult to read. The lore team names 'Order' and 'Chaos' were also a minor aspect that was unknown to many players, which makes the information given unclear and should be renamed to 'Blue' and 'Red'.

The fight feedback was deemed less important than the item feedback, while this fight feedback drowns the item feedback in the text. Players are however unsure whether the item feedback would teach them to correctly pick the item in a following game by themselves. The fight feedback is useful to extract whether the key member of the enemy was killed.

Next to that several additions were proposed by the participants to make the feedback more complete:

- The addition on feedback about CS would also be nice to take the analysis effort from the player. *P6: ' Might be nice to get tips on CS rather than have to analyze it yourself'*
- Addition of when the item is actually bought is also useful so the player can see whether it has an influence on the fights taken. Otherwise he did not know that.
- A deeper analysis would be appreciated. Now the player has to go through the text and draw conclusions, but especially for beginner players this step should be taken out. *P7: 'In my eyes it is still a summary rather than feedback. The analysis could be a bit deeper so you can directly learn from it. For example when you die because of the jungler it would notify you to buy wards and watch your minimap.'*
- The actual feedback is scattered throughout the entire text. A summary about all the fights taken would have been nice at the bottom. That in combination with the text would then have been interesting information that could more easily be used.
- More information about why a certain item is bought is requested as different items give the same stats, but the specific item is stronger on the specific champion. Why is not clear now.

Concept

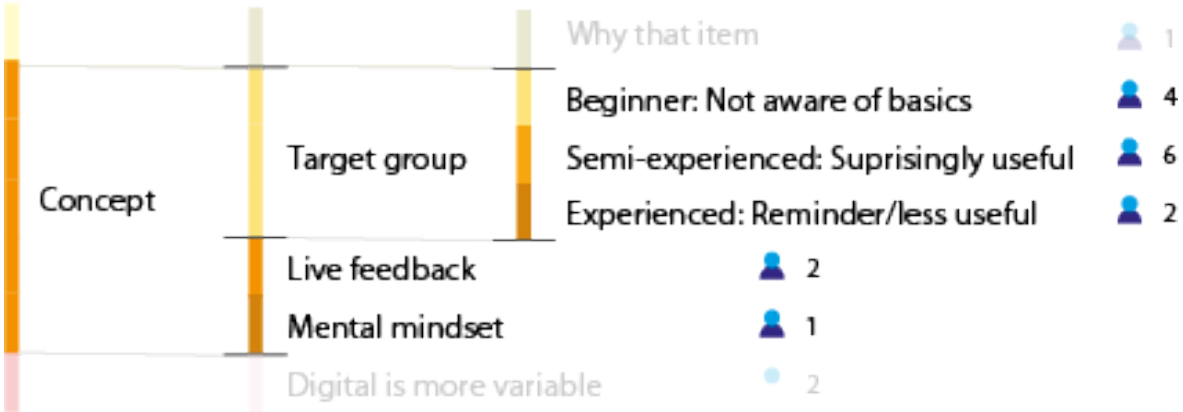

Figure 4.7 Open coding tree: Feedback

The most interesting thing is the different opinions on when the prototype would be useful for a player.

The beginner players were sometimes a bit confused on how to use the prototype since they were also still learning the basic aspects of the game despite having played the game for over a year. They also don't necessarily want to directly put in more effort to learn the game as they aren't as committed towards the game yet. Therefore they couldn't immediately extract data to learn from, but it is an additional tool for them that helps them understanding champions and their strength.

More experienced players mentioned that they, even after several years of playing and a decent rank, could still find use for the prototype in their gameplay. Be it in overall improving their CS, being updated or reminded of champions strengths or the combination of the two it provided an edge to their gameplay that they otherwise wouldn't have had. *P6: 'The prototype is the reason league is interesting for me'*

The better players (higher gold and above) saw less use for their own gameplay as they noticed that they already are aware of item paths, CS, strengths and playstyles of the different champions. They did note that it could be very useful for beginners to help against the extreme learning curve that League brings, but set the cap of the prototype at a way lower level than the average players would, saying that the average players should already know this and that it doesn't provide use for them.

League is also a game in which the mental mindset is very important. The prototype might help in stabilizing a negative mindset through giving a player information on which aspects to focus, but it could also be frustrating.

Physical vs Digital

Interviews

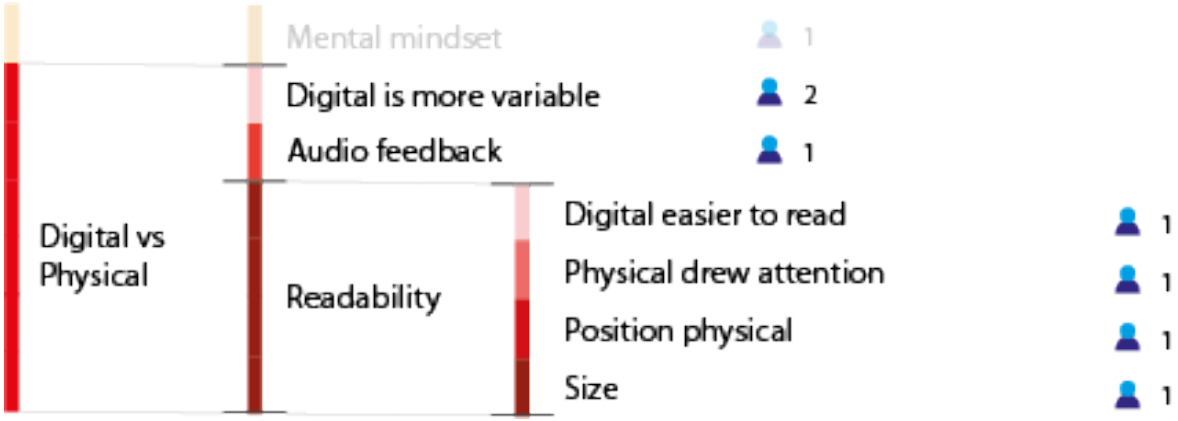

Figure 4.8.1 Open coding tree: Digital vs Physical

Even though no participant experienced playing with both prototypes a few minor differences came forth:

- Digital medium is more variable and additions are easily implemented. For example displaying champion icons, names or summonernames would make linking the slider to a champion easy, but this is difficult to implement in the physical device as it would require more electronics.
- Audio feedback was a nice unintended element of the physical device as it notified the player something changed. It was noted that this aspect could have been explored more widely to increase the immersiveness and effectiveness. This would for example be done through notifying that a new item is advised.
- There was a clear difference in readability between the devices. The CS was misread most of the time as the LED's weren't as easily separated from each other than the circles in the digital version. However at the same time drew the LED's the attention from the player to the device. The item screen was also less easy to read compared to the digital version.
- Because the prototype was lying flat on the table it was difficult to investigate the data. A standing or hanging version would give a nice overview. Also the size made the physical more clear in the powerlevel differences and it gave the physical prototype a calmer feeling. *P13: 'It is nice that it is that big because the small difference are more easily seen.'*

UEQ

The UEQ results were analysed and the different components were visualised in the following graph:

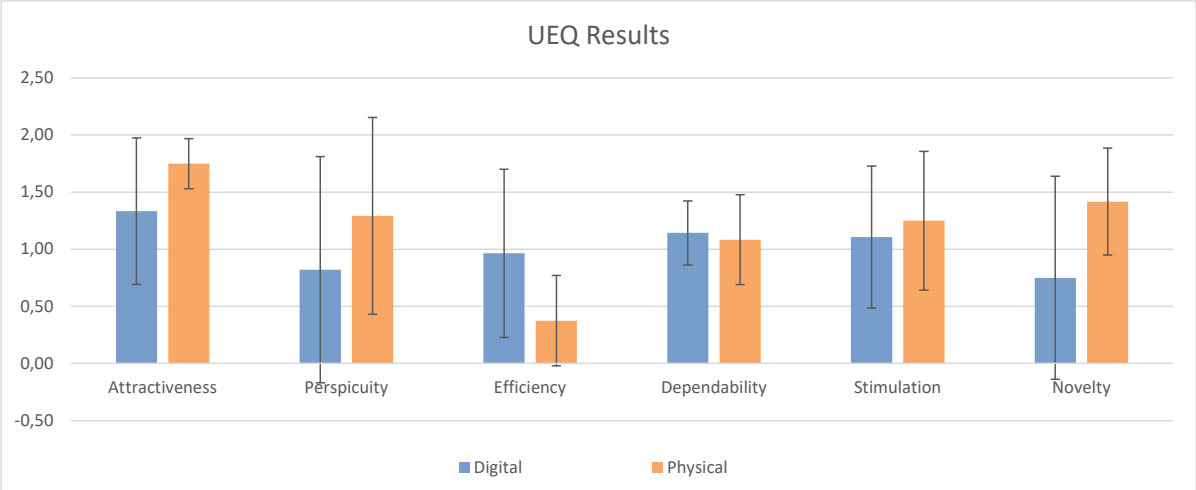

Figure 4.8.2 UEQ Results with standard deviation

The UEQ was only filled in by 13 participants which were then split between two groups. This creates results that are not close to being significant, however it does give a first insight in possible trends and differences between the prototypes.

What comes forth is that both score evenly on dependability and stimulation. Attractiveness and novelty are leading towards the physical prototype, while efficiency is leaning towards the digital one. Perspicuity shows an edge towards physical, but the variance is large in both prototypes, making it difficult to interpret.

The most important element could be efficiency as it the purpose of the prototype is to teach players several aspects and if a version is more efficient in bringing information than that prototype is better. From this perspective the digital prototype would be the better choice as it is deemed more efficient, however if the prototype is more attractive and/or novel this might catch and keep the player's interest. Because of it the player will play longer or more with the prototype which then gives them more time with the prototype to learn. These aspects favour the physical prototype.

GAM

Similarly to the UEQ, the GAM questionnaire was also only filled in by 13 participants. This makes the results far from significant and it only gives a first glance at a direction. On top of that it was noted that during the evaluations the different players had difficulty with the questionnaire and from their questions it quickly arose that they have most likely interpreted the questions differently. Therefore the results should definitely be re-investigated in future research as this makes the results unreliable as they are right now.

When the differences are investigated between the first and second session to find a form of improvement in the player, the following graph comes forth:

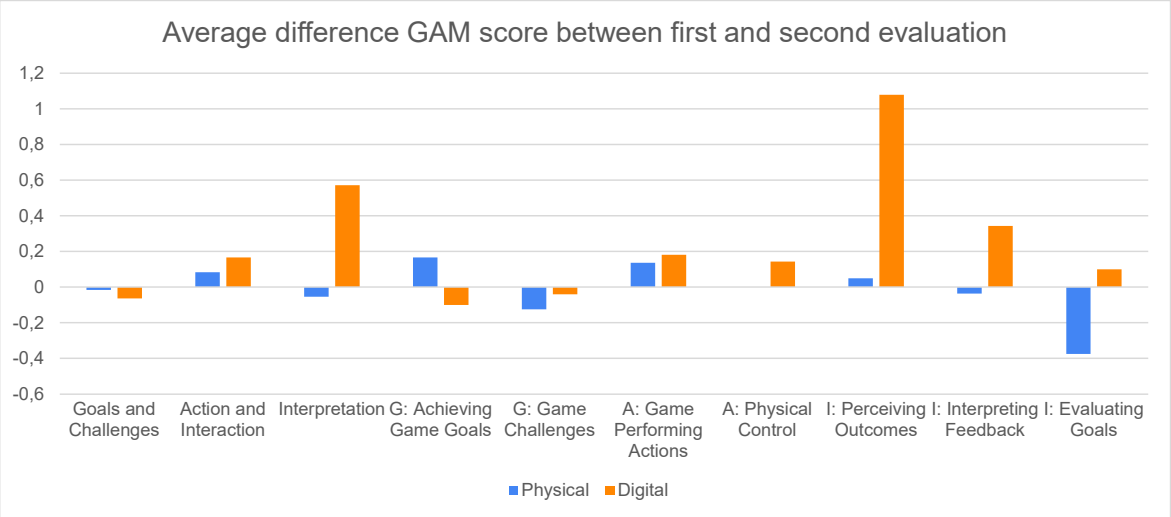

Figure 4.8.3 GAM: Average difference between first and second evaluation

The first three are the main groups with their sub-groups shown afterwards. A 'G' would indicate that it belongs to 'Goals and Challenges', an 'A' to 'Action and Interaction', and an 'I' to 'Interpration'. Both Goals and Challenges and Action and Interaction have very minor differences between the sessions, however the Action and Interaction seemed to have improved the most for digital companion.

The most interesting and maybe most important group 'Interpretation' was won by the digital prototype in every category. This group is the most interesting for the prototype since it desires to create a learning behaviour within the player. If the player is able to interpret the information more easily, which can be seen from the group 'Interpretation' and its sub-groups, than it should perform better.

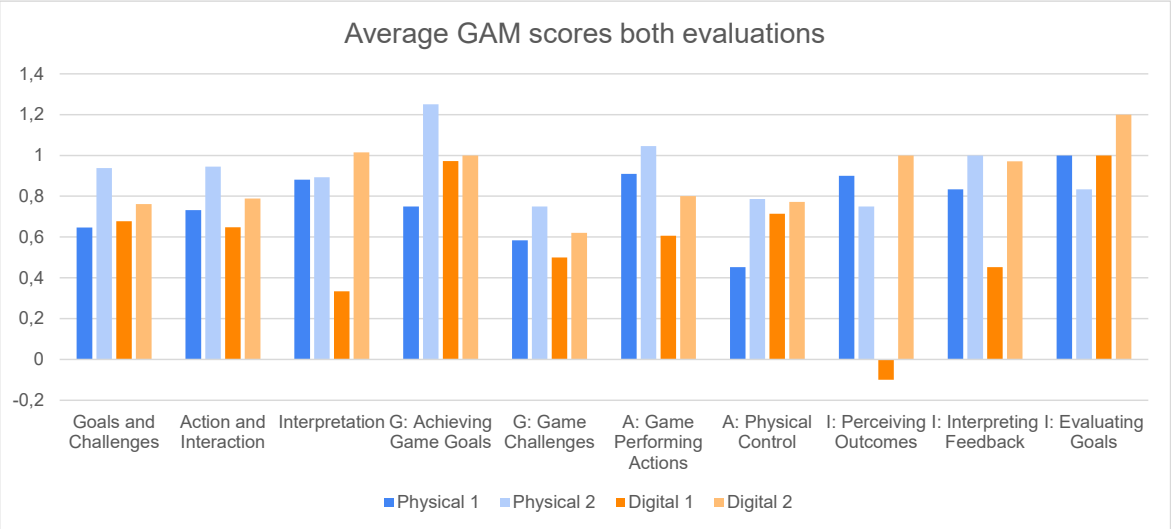

Figure 4.8.4 GAM: Average scores for both evaluations

When we look towards the direct results however it is seen that the physical companion was ahead by a full point in 'I: Perceiving Outcomes' and that the big difference seen in the first graph is created when the digital prototype caught up. Overall the results vary more between the first and second session for the digital prototype. This might have happened because certain players interpreted some questions differently between the first and second sessions as their scores fluctuate from given a 2 to a 6.

Expert

The expert agrees that the product can provide a good helping hand to beginner players and that it's concept is a strong approach, but has a few worries in the informational overload that the prototype might produce. The visualization as it is can also be interpreted in multiple ways and that needs to be taken away from the product. Otherwise the player needs to take additional steps in gathering the information, which takes away the efficiency from the product and adds to the overload that the player gains. An example is the sliders of power levels since they could both point to the middle with the middle being the strongest or that it points to the right and the right side is strongest for both teams. This can be confusing and therefore the opposite of what is meant could be taken from the product. The visualization should be improved to remove these different interpretations. He proposes adding a color gradation or filling one side of the slider with color or light to make it clear from which side it is moving.

Secondly, the clear cases can be drawn from the game itself and most of the time the prototype isn't needed to tell what is going on. Instead the close cases need to be investigated and clear to see from the prototype. For example, a lane in which the player is slightly ahead needs to be visible as he wants to capitalize on this small advantage. This advantage could win him the lane and potentially the match if acted upon. Within the CS a similar case comes forth. Over time the prototype will adjust the goal to the player's level and from there the difference between his performance and his goal will be smaller. However, the player does want to know whether he actually reached his goal, outperformed it or didn't reach it as this will be the main motivation to take that extra step. Otherwise it will be perceived as 'I think I reached my goal' while they actually didn't.

Of course the player will eventually learn to play with the prototype and therefore know how and where to look, but these flaws need to be taken away as the first impression is incredibly important for gamers. If it doesn't stick immediately they are most likely to move past it and look for something else that does meet their expectations. Also, the players are already doing something that is very difficult: League. If the prototype is not easy to use and requires more of the player's thinking process it does the opposite of what it is trying to do: taking a weight of the player's shoulders.

The power levels are in his opinion to learn about a champion during the laning phase or whenever the player is dueling someone in a lane. The differences that make the opponent stronger could then be noted and the player can learn from that to know when a champion becomes strong. In a teamfight this could become too much information. To still be able to extract who is strongest or has the highest impact an addition that highlights the player would be a way to make this easier.

The difference between physical and digital is mainly an effect called 'visual salience'. Because the physical prototype gives different visual cues than the game itself, its information comes forth better. The digital prototype is presented in a similar cue as the game as they are both presented on screen. Because of it the player need to search for the information a bit longer on the screen than the physical prototype. This effect is probably a matter of milliseconds but these are crucial in the environment of League. The game already creates an overload of information and because of the time pressure that the game provides every small time advantage that the prototype can bring is a win. Because of it the player is more likely to create the links between the prototype and the game and thus learn more quickly. This effect is generalizable to other contexts, but has a higher impact within League due to the time pressure.

Lastly, the size of the physical prototype is an advantage as the smaller differences between power levels are more easily seen. The readability improves compared to the smaller digital version.

Discussion

From the results there are no heavy advantages. All differences are minor influences that could give an advantage, dependent on the context. Here a further discussion on the different aspects is given:

The digital medium is more variable and additions are easier implemented into it opposed to the physical one. Adding an element such as colour indications in the power levels or implementing champion names or icons is easier done in the digital version and it therefore has an advantage from the developing and financial perspective. A similar addition to the physical prototype would mean additional electronics and previous versions of the prototype would not acquire this addition.

The unintended audio feedback from the physical prototype was perceived as pleasant. Whenever the motors would be turned on the player knows something changed and looks towards the prototype to see what is changing. Because of it the information comes across more quickly and can be implemented in the game immediately. This audio aspect could be explored more and could potentially be implemented in the digital version in some form, but as it was now the physical prototype had the advantage due to the sound that the motors bring.

The digital prototype was deemed easier to read, however this might've been caused by the positioning of the prototype as it was lying flat on the table. The players could directly look towards the digital prototype and therefore could more easily read the information, whereas the physical prototype was lying flat on the table. Since some players played on a higher table than others the player could not easily tell the difference in power level for example.

The size of the physical prototype however worked to its advantage as it made the smaller differences in power level clearer compared to the smaller digital version. As said by one participant, it gives a certain calm aspect to the prototype which makes it therefore pleasant to use. The information is not condensed into a small prototype, which makes the overload of information less present.

The UEQ showed that the physical prototype was deemed to be more attractive and novel, while the digital one was deemed more efficient. This is however only a first trend as there was only a limited participant number.

Visual saliency might have an impact as well on the efficiency in which the player can retrieve information from the prototype as noted by the expert. Its concept that the human brain looks for the visual cues that are different and therefore important should create a difference in speed of perception [5]. This effect favours the physical prototype as the visual cues it presents are different from the digital game. This however contradicts the UEQ results as the digital version was deemed more efficient.

League is a digital media in itself. Since the players did not know that two versions were made this might have caused a different reaction towards either the digital or physical

version. As there are many digital tools available to help players with various types of information, it might make the digital version less interesting than the physical version just due to the nature of the game. The Halo effect might occur here and influence results. The Halo effect is an effect where the first impression influences future thoughts about the subject. As the physical prototype might be seen as more novel, the participant might value it more while the actual impact is the same [16].

Lastly, during the evaluations it was seen that the target group was different than the group was actually targeted. The prototype could be used from the beginning to some extent, however it mainly helped the players that have been playing for a while and therefore know the basics, but aren't at a high level. These players really benefit from the different functions since they are better at keeping track of multiple things at once, but don't know everything about the game yet.

Limitations

League of Legends in itself is a difficult media to compare between participants, let alone between different prototypes, since the match differs widely between participants. This is essentially the strength of the game as not a single game will play out the same way, but that strength becomes the weakness of the research as no game is the same, making it difficult to compare between participants. League was however selected for the research and design because it is played by a wide community and it has an approachable API, making live data collection and therefore live data visualisation possible.

The digital prototype was tested online, while the physical prototype was tested in person. This was due to the Covid-19 situation that led the researcher to do as much possible from home and not actively visit or draw people to him. However, the physical prototype needed to be with the player when used and therefore these evaluations were in person, opposite to the digital prototype that could be tested online. Normally it would have been chosen to do either a lab study to have the same environment apart from the prototype used, or do the evaluation for both prototypes in person so that the researcher would be present for consistency [9].

The GAM questionnaire was difficult to use and most likely misunderstood or understood differently amongst the participants making the results difficult to use. The participants came forth with multiple questions while they were filling it in, which leads the researcher to believe that the participants interpreted the questions in a different way, which then make the results less valuable to use.

It was chosen to do two evaluations with one prototype above doing both prototype with one session to see if there is potential improvement. Also the Covid-19 situation gave further reasoning for this approach as this meant less participant would have to be seen in person. Ideally the interpretation part of the GAM questionnaire and the CS from the game would show the improvement, however neither could be used in the end to actually show improvement of the player's skill in any way. Since these results could not have been investigated, it would have been more useful for the research for the participant to play a game with both prototypes so that a comparison could be made per participant.

Because of Covid-19 the researcher had to get tested which led to cancelling a few evaluations. All participants had at least one evaluation but the comparison could therefore not have been made for all participants.

Future improvements

In this section future improvements for the design's different aspects are highlighted. In the 'Future recommendations' section the focus lies on the research side of the project and which directions should be explored.

The current concept of the prototype is well received and from the first impression the players believe that the prototype certainly helps in developing a higher skill at a quicker pace. Described elaborately in the findings, but here is a short summary for future iterations to take into account:

The feedback's layout needs to be revalidated and iterated. It is difficult to extract feedback or useful information from the wall of text that the layout now provides, without an active effort and most likely a replay to accompany it. Aspects as colour, whitespace and overall layout should be implemented to make the text readable.
The feedback should also, if possible, be a bit more elaborate and more in depth from the start, taking some of the effort away from the player. As it is now it really needs an active effort to learn something from it. Ideas are for example to further elaborate why a certain item needed to be bought, an analysis on the type of deaths or some feedback on the CS.

The tips needs to be presented in an easier accessible way, maybe with elaborate tips hidden in a dropdown menu or selectable option. The text needs to be shorter as it is too overwhelming at the moment and too much to read.

The CS needs a different visualisation. Right now the goal is difficult to read and difficult to tell whether they are reaching the goal or not. The concept is good in separating the game into segments so the player knows where he is lacking in CS, however difficult to tell when he is close to the middle whether he actually achieved the goal or not.

The proposed items need to take other teammates and different build paths into account next to the enemies as a champion might opt into a different role if his team needs this. Apart from that a small explanation what an item brings the player is requested, so he understands during the game what is going on rather than just from the feedback.

The power levels need to be improved in showing the close matchups. When one is ahead or behind the player can tell from the game state most of the time, however when he is just slightly ahead it is unclear. If this could be shown it would give an advantage as the player wants to capitalise on these small advantages since they can win him the game. Apart from that is further iterating on the algorithm that determines the power level as weird cases still occurred.
Audio is definitely an area which should be explored. From small sounds that notify the player for changes in any of the functions to actually telling the player what to buy is an area that could give the prototype a more immersive feeling and more connected to the game. This could also be used for feedback as a player is more likely to listen to audio feedback than read written feedback [15,19].

Future recommendations

For a further comparison and future research between digital and tangible data visualisation the following subjects should be investigated:

The main direction for future work is a longer term study that is focussed around showing actual improvement within a player's skill instead of just an impression of the prototype. The player would then play with both prototype to make a comparison within that player, opposed to a comparison between participants as players have a different level of skill, play style and level of growth.

In this study it was chosen to perform two evaluations with one of the prototypes per participant. This was in the end not ideal due to the GAM, so in future work it is advised to perform an evaluation with both prototypes rather than one. Through exploring both prototypes with one participant the differences between the two could be explored more easily as the player can tell about the different experiences.

One of the players mentioned that League is mentally a very challenging game and can be very frustrating. The prototype might be a tool to help stabilize this negative mind-set, however it could also upset the player even more. An investigation on the mind set specifically and whether one has a better influence on stabilising and helping the player come back is an interesting unexplored direction. This is mentioned within the gaming scene, but it is also interesting towards situations outside of it as the mind-set is important in every scene where self-improvement is wanted.

There were some differences between the prototypes as they were. Of course they can't be identical to each other as they are presented in a different medium, but for example the CS was not as visible in the physical prototype and the prototypes weren't displayed in the same size, which then favoured the physical prototype. This is proposed over creating the 'ideal' digital and 'ideal' physical prototype to limit further differences for clearer results.

The UEQ showed that the physical prototype was deemed to be more attractive and novel, while the digital one was deemed more efficient. This is however only a first trend as there was only a limited participant number. What however is unknown is which of these qualities has the most impact on the player's learning curve and is therefore the most important. This could be explored to find further advantages to either the digital or physical prototype. These UEQ results are however not significant and should therefore be revisited with a larger participant sample to find if these results are actually correct.
Instead of the GAM questionnaire a different questionnaire needs to be found or created. The GAM gave different interpretations which lead to unusable results. A questionnaire that could measure self-improvement, learning behaviour or reflection behaviour to show improvement in the player's skill outside of the in game systems would be the way to go.

Lastly a more long term direction. The research was perceived in the gaming environment and specifically within League of Legends. Because the gaming environment is a digital medium in itself, the visual salience effect occurs. In a scene where the visualisation would be more of a standalone device, this effect might not occur or have the same impact on the performance. A similar type of research could be done in a non-gaming environment to see whether the findings still hold true or are different.

Conclusion

The product's concept and the design was received well and perceived as useful. Unexpectedly, the design was deemed for a different and broader group than intended including weaker but experienced players as potential users as well. The design still could be improved in various areas, but the concept of receiving live personalised data and feedback about the match was exciting for the players. One wanted to actively keep using the prototype in its current state to continue learning the game.

On the digital versus physical data visualisation matter: no obvious winner could be concluded, but this was as expected. Instead various minor influences were found that should be further explored and could have impact on the effectivity of the design. The context of the design would then determine which type should be chosen. The visual saliency and time pressure that is created by the gaming environment favours the physical prototype, however the versatility and variability of the digital device has advantages within the gaming world as well. Concluding, a set of minor influences was found that could impact the design, next to a set of directions for future work on the visualisation topic.

Acknowledgments

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Reflection

Within the final stretches of the bachelor program I explored and deepened areas that were either not developed enough of interested me the most. If I succeed in passing the FBP I want to leave the department of ID and go towards a more sustainability focussed study. Therefore I wanted to focus on the aspects that are strong within the department and take them to the next step.

For Creativity and Aesthestics I focused on exploring form and interaction. Unfortunately I could not really apply the lessons learned since the prototype couldn't hold many if any interactions, however I did explore the means of rich interaction presented by Frens and Campenhout. Their visions and ideas towards design are certainly useful and presenting different states of a design, and thereby hiding inactive functions, is something I want to take with me towards other future designs. Because of the technical limitations and lack of interactions the principles could not be used, but the research about it already taught me the principles. The next step would be applying them.

For User and Society I focused on involving the user from early on in the design process until the end to really create a product that fits the user's needs. Especially since it focusses on a target group that if there is no match between the product and user immediately, will pass on the device and not use it. I did so through inviting the league community through social media which resulted in a large response group. Using my personal network and expanding it through social media is something I had not done before and it really gave me an advantage since it provided me with a head start for the design process. It wasn't perfect, however, since there were no demographic questions about age or through which medium they were recruited, which made categorizing them difficult. The survey combined with the expert gave a solid base to start from and combined with the evaluations at the end, ensuring that the design incorporated the user's view.

For Math, Data & Computing and Technology & Realisation I believe I put my coding skills to the test and really showed my expertise in the area. With skills that I have never tried before, using an API and creating a functional program, and then combining them, I was able to create a fully functional prototype that used real-time data from the user which was really beneficial for both exploring the product's design as the research. Unfortunately the electrical drawing could not have been made in the end due to time pressure and the lack of importance for the project itself. However this is still an interesting and important skill to learn since it is very important for my vision. With it the energy usage can be calculated, which is important for the my sustainable part of my vision. This skill will therefore remain in my future goals.

Concluding I learned to do a complete project from start to finish by myself and to tackle the difficulties that it brings. I explored the rich interaction principles, implemented the user's perspective throughout the design process and made a working hi-fi prototype with new coding skills. In the future I would like to focus on applying the interaction principles as well as developing the skill to calculate energy usage towards developing skills for sustainable design.

Appendix

I. Community Survey
II. Consent form interview
III. Consent form evaluation
IV. Structure evaluation
V. UEQ results
VI. GAM results

Appendix I: Community Survey

League of Legends Additional Information Products
For a graduation project at the University of Technology Eindhoven the researcher is developing a tool for League of Legends. Later on in this survey the precise purpose of the tool will be explained. The survey will take around 5-10 minutes. The survey is anonymous and no specific details are asked about you apart from your experiences and level within the game.

To start of a few questions will be asked about your level and additional products or services that you use apart from the Riot products. There are many available additional services targeted to different aspects of the game. Think of sites and apps as OP.GG, Blitz, Mobalytics, Porofessor etc. If there is a specific type of data that you use or a specific site/service, please specify why in the last question.

Thanks in advance for filling in this survey!

What rank are you in League of Legends?
- Challenger
- Grandmaster
- Master
- Diamond
- Platinum
- Gold
- Silver
- Bronze
- Iron
- Under level 30

For how long have you been playing League of Legends?
- Under 6 months
- 6 months -> 1 year
- 1 year -> 3 years
- 3 years -> 5 years
- 5 years+

Do you use any products/sites/services that provide additional information besides the Riot Games client?
- Yes

- No

What kind of information are you looking for in these products? (Leave open if you don't use these products)
- Ranks other players
- Champion builds/Itemisation
- Runes & Masteries
- Post-game data and stats
- Live companions and overlays
- Counter picks
- Champion stats
- Spectator tools
- E-sports
- Learning tools and advice
- Different: …

What products/services/sites do you use? (Leave open if you don't use these products)
- Open question

What do you like and specifically use from this product? (Leave open if you don't use these products)
- Open question

Live learning tool
In the end the researcher is going to develop a tangible data visualisation tool that enables the player to set goals and self-improve on basic elements of the game. The device will be a tangible real life object next to your pc so that it can provide feedback on your learning goals while playing the game, without interfering with your game itself through additional layers.

The target group will be the lower skill end and beginning players of the community to give them a useful tool to focus on the basic elements of the game while playing. Right now the goal is to provide useful goals for players up until Gold. If you are at Gold or a higher level please provide feedback on what you struggled with when you were still learning the game and what type of elements will help new players to understanding the game.

Here a few questions will be asked about what type of challenges you encounter as a player and would like to see in a product that stimulates learning the game.
Which aspects of the game would you like to be able to set goals upon within the device and thus improve upon yourself within the game?
- Creepscore per minute
- Gold spending behaviour
- Kill participation/KDA
- Structure objectives (turrets and inhibitors)
- Monster objectives (Baron Nashor and Dragon)
- Itemisation against specific champions/strong opponents
- Effective powerplay with Baron/Elder
- Effectivity in team fights
- Effectivity in solo duels

- Vision score
- Different: …

Please specify why you chose these aspects of the game:
- Open question

In terms of setting goals, in which way would you like the goals to be set?
- A general not modifiable challenge across the various ranks.
- A goal that is set automatically based upon your rank. The device will look at the average score for that rank.
- Manually set the goal.
- A combination of the set examples above.
- The way of setting goals should differ between the type of goal. For example creep score should be modifiable, but gold spending behaviour can be a general goal.
- Different: …

Please specify why you chose this way of setting goals:
- Open question

Would a learning oriented device be something you would be interested in? Why?
- Open question

Appendix II: Consent form interview

Consent Form

Introduction
You have been invited for a user study about self-improvement within the game League of Legends. This study will be conducted by Frans Rijnders from the Department of Industrial Design, Eindhoven University of Technology. You must be older than 18 years to participate in this study. Please read this information carefully and ask the investigator for an explanation if you have any questions.

Procedure
If you agree to participate in this study, you will be asked a set of questions regarding the different aspects of the game, how they influence the game and the player's level and which should be taken as learning goal. The study will be performed online due to the Covid-19 quarantine. This will be recorded for research purposes only. Participation of this study will take approximately 60 minutes. Should you have any questions, please let a responsible researcher know.

Rights
Participation of this study is voluntary. You may refuse to participate or withdraw at any time. You have the right to refuse or withdraw at any time from the recording. The data collected until that time will still be used for the study.

Risks
It is required to look at a digital screen for approximately 60 minutes.

Confidentiality
Your personal data will not be shared by the researcher. All data will be kept confidential by the researchers. Published information about the study will be anonymized. The data will be deleted 1 months after the research has been completed (February 2020).

Agreement to Participate
By signing this form, you indicate that you understood the information and consent to participation in this study.

Additional right
Please check the box when applicable:

☐The video call may **NOT** be recorded for research purposes.

_____

I agree to participate Signature:

Appendix III: Consent form evaluation

Consent Form

Introduction
You have been invited for a user study about self-improvement within the game League of Legends. The product, realized within the theme Tangible Data Visualisation, will be used as a method for self-improvement. This study will be conducted by Frans Rijnders from the Department of Industrial Design, Eindhoven University of Technology. You must be older than 18 years. Please read this information carefully and ask the investigator for an explanation if you have any questions.

Procedure
If you agree to participate in this study, you agree to help in the evaluation of the project, consisting of two small sessions. Firstly, you will download the prototype on your computer. At the beginning of the evaluation you will be asked a few questions and then play a match of League of Legends with the product. Afterwards, you fill in two questionnaires and are asked questions regarding your experience. This will be recorded for research purposes only. One session will take approximately 30 minutes plus the duration of the game. The second session is similar in duration and approach and is taken a few days after the first session. Should you have any questions, please let a responsible researcher know.

Rights
Participation of this study is voluntary. You may refuse to participate or withdraw at any time. You have the right to refuse or withdraw at any time. The data collected until that time will still be used for the study.

Risks
You are required to play (at least) one match of League of Legends on your laptop/PC if possible. The researcher provides you with a prototype with which you play the match. If you have a Mac (Apple computer) you are required to play on the laptop provided by the researcher. The product itself produces no risks apart from flashing lights. Lastly due to the COVID-19 situation the device and laptop are cleaned before the user evaluation, however a small risk remains possible for spreading. If neither are necessary the evaluation will be held online. The measures that could be taken are taken, but if you still don't feel safe you can withdraw.

Confidentiality
Your personal data will not be shared by the researcher. All data will be kept confidential by the researchers. Published information about the study will be anonymized.

Agreement to Participate
By signing this form, you indicate that you understood the information and consent to participation in this study.

Additional right
Please check the box when applicable:

☐The evaluation may **NOT** be recorded at all for research purposes.

_____

I agree to participate ☐ Signature:

Appendix IV: Structure evaluation

Session 1

Demographic information and perspective towards the game

- How old are you?
- For how long have you been playing League?
  - 5+
  - 3-5
  - 1-3
  - 0.5-1
  - 0.5-
- Casual or competitive player?
  - Scale 1 to 7
- What level/rank are you at the moment?
- How often do you play?
  - Multiple games a day
  - Daily
  - Once every other day
  - Few games per week
  - Once or less per week
- Why did you start playing league?
- Compared to then, what do you think about the game now?
- Do you want to improve in the game? If yes, what exactly and why?

Explain the prototype

Play the game

Investigate post game feedback

Questionnaires

- UEQ
- GAM

Post-game interview

- How did the game go?
- What did you struggle with?

Focusing on the prototype:

- Were you able to gather information from it during the game? If yes, what did you learn?
- What information was the most valuable to you and why?
- What didn't you understand or couldn't you use and why?
- (Go over any of the functionalities that aren't mentioned yet)
- Looking back now, what do you think of the different functions?
- What did you learn from this game?
- Looking forward to the next session, what would you like to improve if you are going to use the prototype again?

Session 2
Play the game

Investigate post game feedback

Questionnaires
- UEQ
- GAM

Post-game interview
- How did the game go?
- What did you struggle with?

Focusing on the prototype:
- Were you able to gather information from it during the game? If yes, what did you learn?
- What information was the most valuable to you and why?
- What couldn't you use and why?
- (Go over any of the functionalities that aren't mentioned yet)
- What did you learn from this game?

Concluding evaluation interview
- Would you say you are better than before your games with the prototype?
- If yes, why? If no, do you know what aspects you need to work on because of the prototype?

Appendix IV: UEQ tables

	P3	P9	P7	P3	P2	P11	P8	P4	P10	P5	P6	P1	P12
1	1	1	2	2	2	1	2	2	2	-1	2	2	-1
2	2	3	1	2	1	2	2	2	1	-2	-1	3	1
3	2	1	3	-3	2	3	2	1	0	-2	0	2	-2
4	3	3	-3	-2	1	0	1	3	2	-2	-1	3	1
5	1	1	2	0	2	-1	3	1	2	-2	-2	1	1
6	2	0	2	1	1	-1	2	2	1	-1	1	2	0
7	1	2	2	2	2	1	2	1	1	0	2	2	0
8	0	1	0	0	0	0	0	1	1	0	0	2	1
9	-2	-1	-1	-1	-1	-1	2	2	2	1	0	2	-1
10	1	2	-1	2	-1	2	3	2	2	0	2	-2	-1
11	2	2	1	1	2	2	2	3	1	2	0	2	0
12	2	2	2	2	2	3	2	2	2	2	2	2	0
13	2	2	0	2	2	1	-1	2	1	1	0	2	1
14	2	1	1	2	2	2	2	2	1	1	1	2	-1
15	2	1	2	3	0	1	3	1	0	0	0	2	-1
16	1	1	2	1	1	2	2	2	2	1	0	2	-1
17	1	3	1	1	1	0	1	-1	0	2	1	2	1
18	1	1	3	2	2	1	2	3	1	2	2	1	1
19	2	1	0	1	3	1	2	3	1	2	2	0	1
20	1	0	1	1	1	-1	2	-2	1	-1	2	2	0
21	2	3	1	2	1	0	2	2	0	-1	-1	2	0
22	1	1	-1	1	1	1	2	1	0	-1	2	2	0
23	1	3	2	2	2	-1	2	3	2	-1	-1	3	1
24	2	2	3	2	2	2	2	2	2	2	1	1	-1
25	0	2	2	2	2	2	1	3	2	0	1	2	2
26	1	2	3	1	2	3	2	1	2	1	1	3	-1

Scale	Digital					
	Mean	STD	N	Confidence	Confidence Interval	
Attractiveness	1,33	0,87	7	0,64	0,69	1,97
Perspicuity	0,82	1,34	7	0,99	-0,17	1,81
Efficiency	0,96	0,99	7	0,74	0,23	1,70
Dependability	1,14	0,38	7	0,28	0,86	1,42
Stimulation	1,11	0,84	7	0,62	0,48	1,73
Novelty	0,75	1,20	7	0,89	-0,14	1,64
Scale	**Physical**					
	Mean	STD	N	Confidence	Confidence Interval	
Attractiveness	1,75	0,27	6	0,22	1,53	1,97
Perspicuity	1,29	1,08	6	0,86	0,43	2,15
Efficiency	0,38	0,49	6	0,40	-0,02	0,77
Dependability	1,08	0,49	6	0,39	0,69	1,48
Stimulation	1,25	0,76	6	0,61	0,64	1,86
Novelty	1,42	0,58	6	0,47	0,95	1,88

Table used for the graph 'UEQ' Results on page 21

Appendix V: GAM tables

	P13	P9	P11	P7	P3	P2	AP	P10	P5	P4	P6	P1	P12	AD
1	2	1	3	2	5	4		4	4	3	4	2	4	
2	1	3	3	3	4	3		1	4	3	4	2	4	
3	2	2	5	5	3	2		1	4	1	3	1	4	
4	3	2	2	6	2	2		3	6	2	2	4	4	
5	2	5	3	4	3	3		2	6	2	3	1	3	
6	5	2	5	6	6	3		4	5	1	3	2	3	
G1	2,5	2,5	3,5	4,3	3,8	2,8	3,3	2,5	4,8	2	3,2	2	3,7	3
7	3	3	2	2	3	3		5	4	3	2	2	3	
8	3	3	1	3	2	2		3	4	1	2	3	5	
9	2	3	5	6	5	2		3	5	6	3	2	5	
10	3	2	2	6	5	3		4	3	5	5	3	6	
11	2	2	4	3	6	5		3	6	2	5	3	4	
12	2	2	4	5	5	5		3	6	2	5	2	4	
13	3	1	2	7	6	5		2	6	2	3	2	4	
14	1	1	1	7	2	3		1	6	1	3	2	5	
15	3	1	4	6	2	4		3	6	1	5	2	5	
16	6	2	3	7	6	3		4	3	3	4	3	2	
G2	2,8	2	2,8	5,2	4,2	3,5	3,4	3,1	4,9	2,6	3,7	2,4	4,3	3,5
G	2,7	2,2	3,1	4,9	4,1	3,3	3,4	2,9	4,9	2,4	3,5	2,3	4,1	3,3
17	3	3	4	1	5	1		1	6	6	6	2	2	
18	3	3	3	6	2	3		1	2	2	2	2	3	
19	5	4	2	2	1	3		1	6	3	4	2	3	
20	2	1	1	6	2	3		2	2	2	5	2	5	
21	2	1	2	2	3	2		2	6	1	3	2	3	
22	1	1	3	1	2	3		3	6	1	5	2	3	
23	2	5	3	2	4	5		5	5	1	3	3	5	
24	2	6	3	4	5	3		3	5	5	5	3	5	
25	2	1	2	3	3	2		3	5	1	3	2	4	
26	6	7	6	6	6	6		7	6	3	5	5	2	
27	2	3	3	3	4	3		3	6	3	2	4	3	
A1	2,7	3,2	2,9	3,3	3,4	3,1	3,1	2,8	5	2,5	3,9	2,6	3,5	3,4
28	2	1	3	1	3	3		3	6	3	2	3	5	
29	2	4	4	6	5	2		3	6	2	2	3	3	
30	3	1	3	7	5	5		2	6	2	3	5	3	
31	5	3	6	6	6	5		5	5	6	4	3	2	
32	2	1	2	3	3	3		3	5	1	2	2	3	
33	1	2	4	5	6	6		2	2	5	3	2	1	
34	3	1	2	7	5	2		2	5	3	5	2	3	
A2	2,6	1,9	3,4	5	4,7	3,7	3,5	2,9	5	3,1	3	2,9	2,9	3,3
A	2,7	2,7	3,1	3,9	3,9	3,3	3,3	2,8	5	2,8	3,6	2,7	3,2	3,4
35	3	1	2	2	2	3		4	6	5	4	3	5	
36	5	3	5	1	5	7		6	6	5	5	3	4	
37	2	4	3	3	3	5		5	6	3	2	3	4	
38	3	2	2	2	1	3		2	5	3	3	2	3	
39	5	2	2	5	3	4		3	6	3	5	4	5	
I1	3,6	2,4	2,8	2,6	2,8	4,4	3,1	4	5,8	3,8	3,8	3	4,2	4,1
40	2	1	3	4	4	3		2	5	3	3	1	3	
41	6	7	4	7	5	6		5	6	7	4	6	6	
42	2	2	4	2	3	3		2	3	3	2	2	3	
43	3	1	3	6	3	2		2	3	3	3	2	3	
44	2	2	5	2	4	5		6	6	3	3	2	5	
45	1	2	3	4	3	3		2	5	2	2	3	5	
46	4	1	2	1	1	2		3	6	4	2	2	6	
I2	2,9	2,3	3,4	3,7	3,3	3,4	3,2	3,1	4,9	3,6	2,7	2,6	4,4	3,5
47	2	2	3	2	2	3		5	6	2	3	1	3	
48	3	2	3	6	5	3		1	5	1	2	3	4	
I3	2,5	2	3	4	3,5	3	3	3	5,5	1,5	2,5	2	3,5	3
	3,1	2,3	3,1	3,4	3,1	3,7	3,1	3,4	5,3	3,4	3,1	2,6	4,2	3,7

	P13	P9	P3	P2	AP	P10	P5	P4	P6	P1	AD
1	3	2	3	3		3	5	3	3	2	
2	2	3	4	4		3	4	2	3	3	
3	2	3	2	2		3	5	1	3	2	
4	2	2	4	3			4	2	2	2	
5	3	2	5	2		2	3	5	3	1	
6	3	1	3	3		4	6	1	4	3	
G1	2,5	2,2	3,5	2,8	2,8	3	4,5	2,3	3	2,2	3
7	2	3	2	3		3	6	3	2	3	
8	3	2	5	5		2	6	2	3	2	
9	3	2	6	3		3	5	5	2	3	
10	5	2	4	3		5	6	3	5	2	
11	4	2	6	2		3	2	5	3	2	
12	5	2	5	3		3	6	4	3	2	
13	2	2	6	2		3	2	3	6	1	
14	2	3	5	2		2	5	2	1	2	
15	3	3	4	3		4	7	2	5	3	
16	3	2	3	3		3	7	1	3	3	
G2	3,2	2,3	4,6	2,9	3,3	3,1	5,2	3	3,3	2,3	3,4
G	2,9	2,3	4,2	2,9	3,1	3,1	4,9	2,8	3,2	2,3	3,2
17	4	1	1	3		3	6	3	5	3	
18	2	1	2	5		2	2	2	2	2	
19	2	2	2	3		3	6	2	4	3	
20	2	1	2	2		7	2	2	5	2	
21	3	1	3	2		2	6	1	3	2	
22	5	3	3	5		3	6	1	5	3	
23	3	4	3	5		4	6	1	3	2	
24	2	3	4	4		3	5	1	5	2	
25	2	1	2	3		3	6	2	3	2	
26	6	6	6	6		5	6	1	3	4	
27	3	1	3	3		3	2	1	2	3	
A1	3,1	2,2	2,8	3,7	3	3,5	4,8	1,5	3,6	2,5	3,2
28	3	1	4	3		2	7	3	3	2	
29	2	2	3	3		2	2	2	2	3	
30	4	2	5	5		2	6	5	4	2	
31	3	3	5	5		5	6	5	5	2	
32	3	1	3	3		3	4	3	2	1	
33	4	2	5	3		3	5	3	5	2	
34	3	2	3	5		3	2	2	3	2	
A2	3,1	1,9	4	3,9	3,2	2,9	4,6	3,3	3,4	2	3,2
A	3,1	2,1	3,3	3,8	3,1	3,2	4,7	2,2	3,6	2,3	3,2
35	2	1	3	3		3	6	2	3	3	
36	5	2	6	3		5	2	2	3	2	
37	3	2	6	3		5	6	2	2	2	
38	5	3	3	3		1	7	1	2	2	
39	2	2	6	2		3	5	1	2	3	
I1	3,4	2	4,8	2,8	3,3	3,4	5,2	1,6	2,4	2,4	3
40	3	2	3	2		3	2	2	3	3	
41	7	6	4	6		6	6	6	5	4	
42	2	2	3	2		4	5	2	2	3	
43	3	1	3	3		3	2	1	2	2	
44	2	1	6	3		4	6	2	3	4	
45	3	1	5	3		2	2	1	2	3	
46	1	1	3	3		1	6	2	1	1	
I2	3	2	3,9	3,1	3	3,3	4,1	2,3	2,6	2,9	3
47	4	3	6	3		4	7	1	2	2	
48	2	2	2	3		3	2	3	2	2	
I3	3	2,5	4	3	3,2	3,5	4,5	2	2	2	2,8
	3,1	2,1	4,2	3	3,1	3,4	4,6	2	2,4	2,6	3

	Physical 1	Physical 2	Digital 1	Digital 2
Goals and Challenges	0,645833	0,9375	0,677083	0,761667
Action and Interaction	0,731481	0,944444	0,648148	0,788889
Interpretation	0,880952	0,892857	0,333333	1,014286
G: Achieving Game Goals	0,75	1,25	0,972222	1
G: Game Challenges	0,583333	0,75	0,5	0,62
A: Game Performing Actions	0,909091	1,045455	0,606061	0,8
A: Physical Control	0,452381	0,785714	0,714286	0,771429
I: Perceiving Outcomes	0,9	0,75	-0,1	1
I: Interpreting Feedback	0,833333	1	0,452381	0,971429
I: Evaluating Goals	1	0,833333	1	1,2

Table used for the graph 'Average GAM scores on page 23

	Physical	Digital
Goals and Challenges	-0,01563	-0,06333
Action and Interaction	0,083333	0,166667
Interpretation	-0,05357	0,571429
G: Achieving Game Goals	0,166667	-0,1
G: Game Challenges	-0,125	-0,04
A: Game Performing Actions	0,136364	0,181818
A: Physical Control	1,11E-16	0,142857
I: Perceiving Outcomes	0,05	1,08
I: Interpreting Feedback	-0,03571	0,342857
I: Evaluating Goals	-0,375	0,1

Table used for the graph 'Average GAM differences on page 22