Ranking Factors of Team Success

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ABSTRACT

As an increasing number of human activities are moving to the Web, more and more teams are predominantly virtual. Therefore, formation and success of virtual teams is an important issue in a wide range of fields. In this paper we model social behavior patterns of team work using data from virtual communities. In particular, we use data about the Web community of the multiplayer online game Dota 2 to study cooperation within teams. By applying statistical analysis we investigate how and to which extent different factors of the team in the game, such as role distribution, experience, number of friends and national diversity, have an influence on the team's success. In order to complete the picture we also rank the factors according to their influence. The results of our study imply that cooperation within the team is better than competition.

Categories and Subject Descriptors

J.4 [**Social and Behavioral Science**]: Sociology; H.5.m [**Information Interfaces and Presentation**]: Miscellaneous

Keywords

Online game, Virtual community, Team formation, Statistical analysis, National diversity

1. INTRODUCTION

Team work is important in a wide range of fields and activities. Among others, professional sports and business activities are clear examples where conscious efforts are being made to institutionalize and promote collaborative values and practices. This is also true for the scientific domain, where the role of teamwork becomes increasingly important for the production of high impact science [3].

As an increasing number of human activities are moving to the Web, more and more teams are predominantly virtual. Virtual teams, like any other team, are groups of people that virtually interact while having interdependent tasks guided by a common purpose. The formation and success of virtual teams is an important topic in developing flexible organizations. Enterprises can now benefit from virtual interaction in environments where teamwork would have once been impossible, accessing previously unavailable expertise, as well as retaining the advantages of flat organizational structures [30]. Therefore, study cases of virtual teams have mainly focused on the entrepreneurial context [19, 27]. However, as the Web is an intrinsic part of modern society, it provides an unprecedented opportunity to extensively observe social interactions in different contexts on a larger scale.

Online games have already been widely used to study social interactions. These environments reflect human psychology and behavior by recording individual actions and team transactions. Moreover, they can be considered as global research contexts because of their geographically distributed population. The nature of the teams is also very diverse with respect to team size, composition, strategies and goals [5]. The so-called Massively Multiplayer Online Role-Playing Games (MMORPGs) are used as the main scenario to study online interactions in this context.

Empirical research has shown that team composition influences team success [5]. Following this approach, we aim to develop an understanding of cooperation within teams and the influence of cooperation on success. To this end, we study the community of the multiplayer online game Dota 2 [31]. In this game two teams, consisting of five members each, are pitted against each other with the task of defeating the opposing team. To achieve this goal, close cooperation and intelligent interaction between the members of the team are needed – a challenge that mirrors many "real world" situations. In MMORPGs player cooperation is possible while making his/her own progress and having individual tasks. Dota 2, in contrast, is a game in which the players are always assigned to a team and thus have common goals and interests.

In our studies we investigate the influence of several factors on teams' success. Our previous work gave evidence of the influence of role distribution, previous experiences and

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friendship ties on a team success [22]. This paper supplements our previous results providing a more detailed analysis of those factors and analyzing the impact of teams' national diversity. Besides this, we rank the importance of these factors according to their influence on the teams' success. Furthermore, most of the existing studies use qualitative approaches such as questionnaires, to learn about the behavior and the motivations of users. We, on the contrary, base our study on a large volume of in-game event logs that are generated from the actions of each player. This quantitative approach offers a better understanding of the factors that influence the formation of a successful team.

The rest of the paper is organized as follows: In section 2 we explain the relevant game mechanics. In section 3 related work is presented. Descriptive statistics of the data are provided in section 4. The results of the previous work are summarized in section 5, and sections 6 and 7 presents further analysis and results. Our conclusions and plans for future work are presented in section 8.

2. THE GAME AND ITS COMMUNITY

Dota 2 [31] is a so-called multiplayer online battle arena (MOBA) video game developed by Valve [33]. Each player controls a character called "hero", who participates in a team combat with the objective to demolish the opposing team's fortified stronghold. We are aware that this is a very cruel terminology, but we stick to it since it stems from the game creators.

Players are pitted against each other as two distinct factions of five players each, the *Radiant* and the *Dire*. Their strongholds, called *base towers*, are located at opposing ends of a geographically balanced squared map (see Figure 1). These are connected by three main lanes, which are guarded by defensive towers and weaker computer-controlled units, called *creeps*. Killed heroes revive in the corresponding area of their base after a waiting time proportional to their level and the game time. Through the destruction of enemy forces, heroes may gain both experience and gold. The former accumulates to gain higher levels that enhance the hero's attributes and abilities. The latter is the currency of the game, which is distributed to the team members according to their accomplishments. Gold also accumulates periodically to each hero. It is mainly used to acquire items that substantially complement or alter abilities, as well as to buy an instant revival of the hero.

Each player selects one hero out of 96 available in Dota 2. These heroes are unique characters that differ in their initial attributes and special abilities. On the one hand, initial attributes categorize heroes primarily according to their strength, agility and intelligence. On the other hand, special abilities are a set of four unique spells specific to each hero (for example, there are such spells as "Enchant totem", "Greevil's greed", "Nature's guise" and so on). Both attributes and abilities are enhanced with experience accumulated over the course of the game. Through the combination of initial attributes and special abilities different heroes are suited for different strategies (in Dota 2 they say game "roles") and can be played in a variety of ways (e.g. "Pusher", "Carry", "Nuker", etc.). Each player chooses a strategy not only based on the selected hero, but also on the heroes of the other members of the team. Through the choices of these strategies the flexibility of the team is increased; this facilitates the formation of more competitive teams.

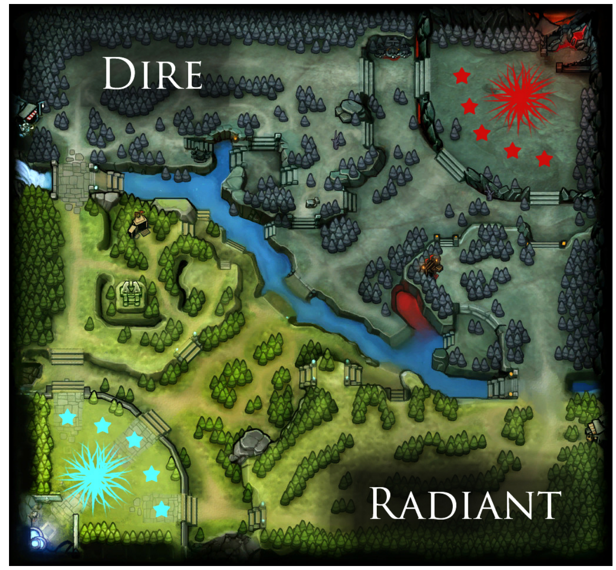

Figure 1: Map of Dota 2 (from Dota 2 wiki [7]).

To get more details about each attribute, ability as well as game role, we recommend to address the official wiki page of Dota 2 [7]. In Table 1 we present three heroes from Dota 2: "Treant Protector", "Phantom Lancer" and "Lina". We also provide the values of their main three attributes ("Strength", "Intelligence" and "Agility") as well as class to which they belong and game roles in which these heroes can be played.

Dota 2 is a team-oriented game in which strategy and team coordination is decisive to achieve a victory. Communication between team members is a vital part of the game, acting as a binding force that makes a team function. Players can communicate through typing, voice chat, pinging the map and writing on the minimap.

Valve has built a social network around Dota 2 utilizing Valve's Steam software [32] in order to provide social and community functionality for the game. Steam accounts save personal files and settings on the online accounts. The players can set up private games with friends or join public games. In private games, teams might, however, be formed not only by humans, but also by Artificial Intelligent (AI) bots. In this case other players in the community are locked out and the game is played with computer-controlled heroes, who can also interpret simple commands of human players. Dota 2 has not been publicly released yet. Even if its beta version limits its test early access, it is currently one of the cornerstone games at several electronic sports tournaments, and considered one of the best and highest e-sport games [11, 25, 14].

3. RELATED WORK

Virtual worlds are playing an important role in the study of diverse fields such as sociology [16], psychology [36, 8], economy [20, 24], etc. These studies raise the question of how the mechanisms of human behavior are being translated and developed in an artificial environment. Teams within virtual communities have also been the focus of attention of a number of studies. Early studies described their characteristics agreeing that such teams are more diverse than conventional teams, with members representing not only differ-

Table 1: **Examples of heroes with some of their characteristics (from Dota 2 wiki [7]).**

			
Class	Strength	Agility	Intelligence
Strength	25	18	18
Agility	15	23	16
Intelligence	17	21	27
Game role	Durable Initiator Lane support Disabler	Carry Escape Pusher	Nuker Disabler Support

ent geographical locations, but also cultures and languages [10, 18]. More recent studies are contributing to the understanding of the differences of face-to-face team collaboration opposed compared to a virtual one [17, 19].

Gameplay data and player characteristics are drawing the attention of recent studies in the field of social computing and web science [21]. In particular the study of Massively Multiplayer Online Role-Playing Games (MMORPGs) are gathering most of the attention. This is due to their nature that allows players' cooperation and competition on a large scale, as well as interaction assuming the role of a character whose actions can be controlled, in the case of MMORPGs. The social interactions that take place in them are well explored demonstrating the crucial role that they play. Cole et al. [4] examine them through the analysis of online questionnaires that interrogate about social interactions that occur both within and outside MMORPGs. Their results show that these are extremely social games that favor the possibilities of players making life-long friends and partners. Recent studies analyze log data of this kind of games with the aim to build models of human features and behavior, such as activities, interactions and cooperations [29].

Kałuża et al. [16] used the MMORPG *World of Warcraft* as a case study that they analyze from a sociological viewpoint. In their study they identify players' communication as a driver for community engagement. Their descriptive research concludes that origin, culture and language are important factors of player attractiveness that have an effect on the creation of national guilds, communication problems and generalization of players' behavior based on the country of origin. The significance of cultural issues has been corroborated by Jacobs [15], who qualitatively analyzes racism, nationalism, and culture wars within multicultural Internet communities such as the MMORPG *Omerta*. These conclusions, however, have not been accompanied by concomitant research efforts to quantitatively demonstrate the impact of geographical, cultural and linguistic factors on the MMORPGs team's success. Existing quantitative studies that analyze the geographical distribution of MMORPG players mainly focus on the prediction of the servers workload, and players' subscription and disinterest in the game [35, 26].

Group formation of gamers is also examined in one of the latest studies of Keegan et al. [17] who collected data about characters and accounts from the Sony Online Entertainment's MMORPG *EverQuest II*. Cooperation and competition in online games is examined by Yuan et al.[37] by conducting a quantitative study and analyzing game logs. Their results show that the selection based on in-game score level of partners to cooperate with is important for the players, while choosing the opponents is slightly biased.

The categorization MOBA (Multiplayer Online Battle Arena games, also known as Dota-like games, often refers to games with two teams of players competing against each other and controlling a single character in the battlefield. Although this genre emphasizes a more cooperative teamplay, the literature about it is very scarce. A very recent paper analyzes the relationship between real life leadership styles (authoritarian, democratic or laissez-faire) and game roles of two MOBA games, Dota 2 and *Heroes of Newerth* [23]. The method used was a close-ended questionnaire to examine daily life and gameplay behaviors.

Dota 2 as a game differs from MMORPGs since this is first of all a team game and only afterward a game with elements of traditional MMORPGs. The team perspective is the main focus of our analysis, which is based in previous work [22]. We are not aware of any other recent work using game log data to analyze the behavior and interaction of MOBA players, and with our studies we aim to cover the gap.

4. THE GAME AND ITS DATA

The data set, which is used for this study, has been retrieved in XML from Steam and Dota 2 utilizing their Web APIs [34, 6] and was afterwards migrated to PostgreSQL. The data was made public by the community of Dota 2 players, and contains the match history as well as details of the matches that were played in the year 2011.

Using the Steam API we incorporate additional information of those players that appear in the match history of the Dota 2 data. This information is extracted from the players' profiles on the Steam platform. Such profiles contain personal information such as name, country, sign up date, last log off date, etc. The list of friends of the social network is also extracted (see also Section 2). However, the accessibility of this information dependents on the confidentiality status of the user profile, which can be public or private.

The data set includes information on 885,228 matches. Since we focus on team aspects, we need details about both the matches and the players involved, such as:

- Start time and duration of a match;
- Outcome of a match (i.e., which team wins);
- The number of human players in a team (there are also teams that include AI bots – see Section 2);
- The difficulty or "skill" of a match (there are four different levels – *low*, *normal*, *high* and *very high*);
- Account ids and additional information on the players, such as their countries;
- Heroes chosen by a player as well as the performance of those heroes in the match (i.e., how often they are defeated, how many others they damage, how much gold they acquire and so on).

For the majority of the matches in the data set not all this information is provided, so we filter them out. Also we keep only the matches that contain two teams with five players in each team and all players have public profiles.

The filtered data set comprises 87,204 matches, which are played by 138,101 individuals. 71,874 out of those 138,101 players (i.e., 52%) indicate their country. In total, the players come from 233 different countries; the top 10 countries are: USA (16,032 resp. 22.3%), Russia (13,799 resp. 19.2%), then Canada, Sweden and Germany (approximately 3,800 resp 5.4% each), Ukraine (2,711 resp. 3.8%), Great Britain (2,253 resp. 3.1%), France (1,503 resp. 2.1%), Finland (1,311 resp. 1.8%) and Poland (1,175 resp. 1.6%). Thus, as it can be seen in Figure 2, only 10 different countries account for approximately 70% of the players (50,396 out of 71,874).

Overall, there are three predominant regions – Eastern Europe, Western Europe and North America. About 29.2% of the players (approximately 21,000) are located in each of them. So in total, about 90% of the players come from these three regions. Considerably fewer players are from Asia (7%), South America (2.6%), Oceania (2.5%) and Africa (1%). It should be noted that the distribution of players does not represent the world population nor the population of Internet users. This puts some limitations on our results.

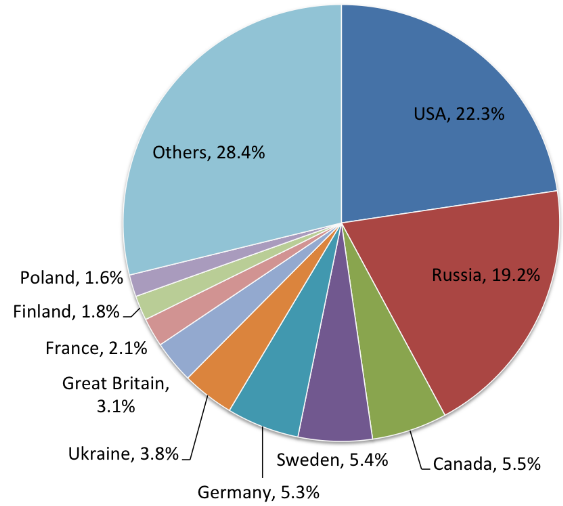

Figure 2: The top 10 countries where the players come from.

5. PREVIOUS RESULTS

In this section we shortly summarize the results of our previous paper [22] which we are building upon. We show how different factors (i.e. role distribution, previous experiences and friendship ties) influence team success in a virtual environment.

The first factor under our consideration was the role distribution within the team. To analyze it, we calculated a unique *hero score* for each hero of Dota 2. For this purpose we incorporated additionally data about initial attributes of the heroes. Then we took data about heroes selected by the players and outcome of the matches (872,040 data points for 10 players in 87,204 matches) and trained a logistic regression model on 70% of observations from our data set. In the end, the calculated coefficients were applied to the rest of our data set.

Another factor which influences the team success is the experience of players. As for the gaming experience of players, we considered not only information about the amount of previously played and won matches and the played time, but also information about performance in previous matches. After a match ends each player receives statistics about his/her performance which includes 13 different measures such as #kills, #deaths, spent gold, final level and so on. In total we get 17 different attributes related to the gaming experience of each player. Following the same reasoning as for hero selection, we used logistic regression on experience attributes to calculate an *experience score* for each player in a specific match.

Figure 3 shows the results of a Spearman correlation test (i.e., correlation coefficients and their significance) and scatter plots between *hero score*, *experience score* and *win* on the data set which we use to calculate the scores. Variable *win* is binary and indicates whether a player was in the winning team (value 1) or in the losing team (value 0). Variables *hero score* and *experience score* are numerical and range from 0 to 1000 according to the way we calculate these scores. As we see, there is a significant high correlation coefficient (63%) between *experience score* and *hero score*. This observation can be explained by the fact that the higher gaming experience of the player, the better he/she is at choosing heroes. The correlation with variable *win*, though significant, is very low: for *hero score* it is 2.1% and *experience score* it is 1.7%. However, with further analysis we could show that the team composition is an important factor for the match outcome. These are explained in our previous paper [22] and summarized in the following.

We tested whether the role distribution (i.e., selecting a specific hero) is important for the team success. For that

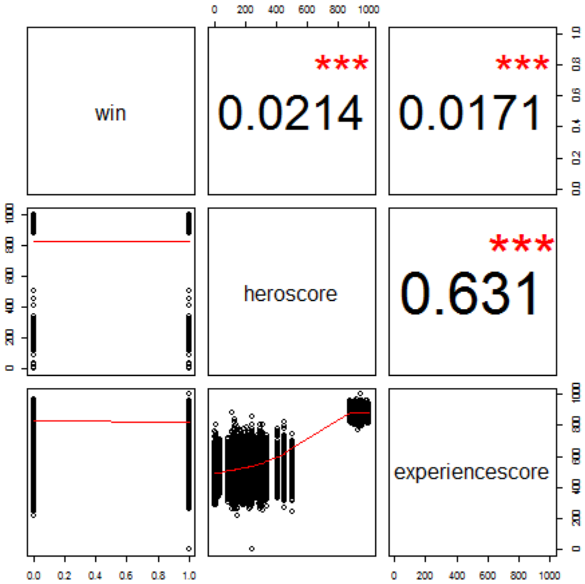

Figure 3: Correlation coefficients, their significance and scatter plots between *hero score*, *experience score* and *win*. Significance levels: $^{*}p < 0.1;^{**}p < 0.05;^{***}p < 0.01$.

purpose we calculated the *team hero score* for each team in a specific match as the average of *hero score* for the heroes selected by the team members. We formed two normally distributed samples, containing the scores for the winning and losing team and tested whether the mean difference of *team hero score* of these samples is equal to zero. We found that *team hero score* positively influences the team success.

To analyze if experience impacts the result of the game we calculated a *team experience score* for each team in a specific match as the average of the *experience scores* of the team members. Again we formed two normally distributed samples, containing the scores for the winning and losing team. We tested the dependence of team success on *team experiences score* and found that a winning team has on average a higher *team experience score* than a losing team.

In order to study if playing with friends influences the outcome of a game, we calculated the maximum number of friends that each team player has in the team. We called it *max # friends*, which ranges from 0 to 4. We could conclude that *max # friends* and the outcome of the game are dependent variables. Furthermore, we checked how the number of friends influences the team success. We formed two samples with *max # friends* for the winning team and losing team. As a result, the mean amount of friends for winning teams is significantly higher than for the losing teams.

Summarizing the findings for our previous work, we can provide evidence for the following accepted hypothesis:

1. a better role distribution in a team increases the possibilities of a successful outcome;
2. teams with more experienced players are more likely to win;
3. playing with friends increases the chance to win.

In the following section we examine the teams' national diversity as another factor of team success.

6. NATIONAL DIVERSITY

Here *national diversity* is defined as the number of distinct countries the members of a team come from. To analyze it, the following statistical tests are applied:

- In order to test if the number of distinct countries within a team and the outcome of the game are independent, χ^2-tests are performed.
- In cases where we have only two groups (e.g., when grouping countries) and we want to investigate if there is a dependency between the group a team belongs to and the outcome of the game, Fisher's exact test is applied. The reason is that for small contingency tables this test is more accurate than the χ^2-test([2]). When performing Fisher's exact test, R ([1]) moreover, also calculates the odds ratio. In case of a dependency, this ratio indicates which teams are more likely to win – those of the first group or those of the second one.

As discussed in Section 4, not all the players report their country. For our analysis we keep only those teams where the country is known for all of its members. This is true for 8567 teams. A summary of the filtered data set is given in Table 2. We see, for example, that teams, where all five members come from the same country, win in 391 out of 778 cases; and teams, where the players are from two different countries, win in 1229 out of 2362 cases. We would like to stress that there is no opportunity to verify that the country indicated by the player is credible.

Table 2: National diversity.

#Dist. Countries	*#Matches*	*#Wins*	*Win Rate*
1	778	391	50.25%
2	2362	1229	52.03%
3	2818	1374	48.76%
4	1957	987	50.43%
5	652	313	48.01%

As it is indicated in Table 2, it seems that there is no dependency between the number of distinct countries within a team and the outcome of the game. We perform a χ^2-test that confirms this impression ($\chi^2 = 6.7942$, *p-value* $= 0.1472$).

Since there is no dependency we take a deeper look into the data and divide it into two groups (see also Table 3):

- Group A: Teams with members from one or two different countries. Those teams have a win rate of 51.6%.
- Group B: Teams with members from three or more different countries. Those teams have a win rate of 49.3%.

We apply Fisher's exact test to check whether the difference in the win rates is statistically significant. We get a *p*-value of 0.039 and thus a small evidence that there is a dependency between the outcome of a match and the group a team belongs to. Furthermore, the odds ratio of 0.9073 indicates in this context that teams of group A are slightly more likely to win than teams of group B – which implies that teams with one or two different countries are more likely to succeed than teams with three or more different countries.

Table 3: Division into two groups.

Group	*#Matches*	*#Wins*	*Win Rate*
A	3,140	1,620	0.516
B	5,427	2,674	0.493

In a further exploration, we also take into account the difficulty of a game. Hence, we differentiate the matches according to their skill level, which is an indicator for the difficulty (see Section 4). There we get 4061 matches of skill level 0, 3796 of skill level 1 and 710 of skill level 2.

When looking at those categories separately, we obtain the following results (see also Table 4):

- For matches of skill level 0 there is a statistically significant dependency between the number of distinct countries within a team and the outcome of the match (p-value smaller than 0.05).
- For matches of skill level 1 and skill level 2 no such association can be found (both p-values larger than 0.05).

Table 4: χ^2-test of independence for different skill levels (between number of distinct countries in a team and outcome of the match).

Skill Level	χ^2	*Degrees of Freedom*	*p-value*
0	15.5909	4	0.00362
1	6.2129	4	0.1838
2	3.8898	4	0.4211

Thus, we take a closer look at matches of skill level 0. Table 5 provides more details on the number of distinct countries and the win rates of teams playing in matches of skill level 0.

Table 5: Matches of skill 0 – national diversity.

#Dist. Countries	*#Matches*	*#Wins*	*Win Rate*
1	339	179	0.528
2	1,132	616	0.544
3	1,329	632	0.476
4	934	444	0.475
5	327	159	0.486

In Table 5 we also see that the win rate depends on the number of distinct countries. So we again divide the teams into two groups: Group A comprises all teams where the members are from the same country or from two different countries. Teams where the players come from three or more countries belong to group B. The number of teams in each group and the win rates are indicated in Table 6. Fisher's exact test shows that there is a strong association between the outcome of the match and the group the team belongs to (*p-value* = 0.001). The odds ratio of 0.775 implies that teams of group A, i.e. teams with a low number of different countries, are more likely to be successful.

Table 6: Matches of skill 0 – division into two groups.

Group	*#Matches*	*#Wins*	*Win Rate*
A	1,471	795	0.540
B	2,590	1,235	0.477

In summary, it can be said that a team performs better if its members are only from one or two countries. This is especially true for matches where the players are not so advanced yet, i.e., matches with skill level 0. Nevertheless, as we show, this appears not to be an advantage any more if the matches get more difficult.

As Dota 2 is a game in which close coordination and smart interactions are important for the success of a team, it is no surprise that team members that have the same background and speak the same language have an advantage over teams that can not communicate so easily. However, our results clearly imply that if the players become more advanced, it is not crucial how a team is composed in terms of nationality – its performance does no depend on it.

7. RANKING FACTORS

Up to now we have shown how and to which extent different factors, i.e., hero score, experience score, max # friends, national diversity, have an influence on the game outcome. In order to obtain a more complete picture we would like to rank these factors. However, since only few players indicate their country of origin and according to the low significance of the dependency test of national diversity on the game outcome, we exclude the factor *national diversity* from this analysis. Therefore, we analyze which of the three factors (*hero score*, *experience score*, *max # friends*) have the strongest influence on the team success and whether the influence of these factors is preserved if we consider them together.

For this purpose we perform log-linear analysis. We first normalize the scores and fit our data into the logistic regression model in R [1] since the game outcome is a binary variable. Afterwards, we perform analysis-of-variance (ANOVA) on the fitted model to explore the deviance. We use type III tests since they test each term in the model after all of the others [12]. Since we have both categorical (i.e., *max # friends*) and numerical factors (i.e., *hero score* and *experience score*), we use Wald's and likelihood-ratio χ^2-statistics.

According to the results (see Table 7), *max # friends* has the highest deviance and can be considered as the most influential factor. However, *hero score* and *experience score* have also significant influence. In Table 7 column "Df" shows the degree of freedom for the corresponding factor.

By using Wald statistic instead of Log-likelihood Ratio (LR) one from Table 7, we check what is the influence of intercept on the game outcome – this is a constant introduced by the logistic regression model in R. Table 8 presents the results of ANOVA performed with Wald test, indicating that intercept is a significant term, but with deviance lower than that of the other three factors.

Table 9 summarizes the information about the fitted logistic regression model which we used for ANOVA in Tables 7

Table 7: Type III test with likelihood-ratio χ^2 statistic. Significance levels: $^{*}p < 0.1;^{**} p < 0.05;^{***} p < 0.01$.

Factor	χ^2	*Df*	*p-value*
experience score	72.7279	1	$1.4881e-17$***
hero score	89.8186	1	$2.6102e-21$***
max # friends	210.5955	4	$1.9782e-44$***

Table 8: Type III test with Wald χ^2 statistic. Significance levels: $^{*}p < 0.1;^{**} p < 0.05;^{***} p < 0.01$.

Factor	*Df*	χ^2	*p-value*
constant term	1	48.097	$4.056e-12$***
experience score	1	72.667	$1.534e-17$***
hero score	1	89.727	$2.733e-21$***
max # friends	4	210.023	$2.626e-44$***
Residuals	174397		

and 8. Our previous work has also demonstrated that *hero score* and *max # friends* positively influence the game outcome which is coherent with the coefficients of these factors in our fitted model. Moreover, we showed that the bigger amount of friends play together, the bigger the chance to win, and in our fitted model the coefficient for *max # friends* = 4 is the highest. This result also confirms our previous findings.

In addition, in our previous work we showed that the *experience score* positively influences the success of the team (see Section 5 and our previous work [22]). Moreover, in Figure 3 the correlation coefficient between *win* and *experience score* is positive. However, the coefficient of this factor in the fitted model is negative (see Table 9). This is a contradiction.

To explain the obtained contradiction we conduct a partial correlation test (see Table 10). The results of this test show that the correlation coefficient between *win* and *experience score* becomes negative given *hero score*, but with a very small coefficient (around 2%). Our first understanding of this observation is that if players with less experience manage to select heroes as well as the opponents with more experience do (i.e., both teams have the same *team hero score*), then the first must have some hidden potential which is negatively accounted for in the *experience score*. This calls for futher investigation.

We have also constructed the full logistic regression model on our data, i.e., using not only each factor separately as shown above, but also considering all possible combinations of these factors. The ANOVA shows that the model does not improve if we consider partial combinations of the factors.

In the last step, we can rank factors in decreasing order according to the strength of their influence on the team success (see Tables 7 and 8):

1. *max # friends* which measures the social ties inside the team;
2. *hero score* which is the indicator of role distribution inside the team;
3. *experience score* which is the aggregate measure of experience of the team members.

Table 9: Summary of the Logistic Regression Model.

	Dependent variable:
	win
experience score	-0.144^{***}
	(0.017)
hero score	0.160^{***}
	(0.017)
max # friends = 1	0.038^{***}
	(0.012)
max # friends = 2	0.108^{***}
	(0.014)
max # friends = 3	0.191^{***}
	(0.019)
max # friends = 4	0.283^{***}
	(0.026)
constant	-0.067^{***}
	(0.010)
Observations	174,404
Log likelihood	−120,746.300
Akaike Inf. Crit.	241,506.600
Note:	$^{*}p < 0.1;^{**} p < 0.05;^{***} p < 0.01$

Table 10: Summary of partial Spearman correlation test with game outcome (variable *win*).

Factors	*Coefficient*	*p-value*	*Statistic*
win	1	$0.00e+00$	0.000
experience score	−0.0184	$1.623e-14$	−7.6774
hero score	0.02379	$2.8754e-23$	9.9369

This list shows that playing with friends is the most important factor for winning the game. Additionally, we need to have a good distribution of roles inside the team. The last factor according to its contribution to the explanation of variance is experience. It is worth mentioning that *team experience score* is just an aggregation of individual *experience scores* for each team member and does not consider the experience of the team as a whole. Thus, it is clear that this factor has the least influence out of all three factors. All put together can be interpreted that cooperation and social ties (in other words playing with friends) inside the team is more crucial for the team success than individual skills of team members.

8. CONCLUSIONS AND FUTURE WORK

We use the data from the online game Dota 2 and its community to treat the questions of factors for team success. We provide small evidence to support the hypothesis that national diversity influences the game outcome. Here there are two points which need to be considered. First of all, there is no opportunity to verify the country which the player indicates in his/her profile. Secondly, when analyzing the national diversity of a team we considered only the amount of distinct countries from which the players come. In the future we will also investigate the cultural distance of the members of a team as shown by Shenkar [28].

We rank the factors of team success discovered in our previous work according to the strength of their influence:

1. *max # friends* which measures the social ties inside the team;
2. *hero score* which is the indicator of role distribution inside the team;
3. *experience score* which is the aggregate measure of experience of the team members.

Thus, the most important indicator for the success of the team is the number of friends playing together in the team, especially at the beginner levels of the matches. Moreover, it is better if they come from the same country. The least influential factor is the *team experience score* which, given the way it is calculated, is not surprising: this score summarizes only individual skills of all team members, but not of the whole team. This implies that cooperation is better than competition inside the team within the game Dota 2.

Furthermore, our results show that data on online gaming and gaming communities can be used to infer social behavior patterns. However, we simplify team dynamics considering only three aspects, which are studied as independent variables. In the future we plan to extend the model to ensure that the influence of these three factors is not due to other hidden factors like gender or age. It could be also introduced a more sophisticated measure of role distribution inside the team, e.g., by taking into account not only heroes selected by each team member, but also weighting each choice with the previous experience with the selected hero. Since we find evidence that cooperation is better than competition inside the team, we will consider the introduction of a new score to measure individualism and collectivism of a player. Hofstede argues in his book [13] that such measure influences work related values.

As we have seen, the existence of friends within a team influence the performance of that team in a clearly positive way. Thus, in a next step, we plan to study the central role that this factor plays in the composition of teams in more detail. With the help of network analysis techniques we want to take a deeper look at the friendship networks of the players on Steam platform (see also Section 2). In our current work we only take into consideration the maximum number of friends within a team (i.e., "direct links" in this friendship network) and its impact on the team's success. In a next step we want to factor in additional, structural information. We will look, for example, at the average distance of the team members within the friendship network or if the team members form a clique (i.e., a complete subgraph) in order to identify structural properties and patterns that influence the outcome of a match in a positive way. We might also be able to answer the question whether players of the game become friends because they play together or rather they convince already existing friends to join the game.

Besides the friendship network that is explicitly given on the Steam platform, we will study in our future work networks that are implicitly given in this context. For example, we will use our data to construct a co-playing network. This might help to investigate how often subgroups of the team members as well as the team as a whole have already played together before. Network analysis techniques can then also lead to deeper insights into both the *local* structure (i.e., clusters of individuals that often play within a team) and the *global* structure (i.e., number and size of connected components, density, and so on) of such a co-playing network.

One of the limitations of our findings is that we have provided quantitative evidence for success factors only on a gaming data set. Therefore, another direction for our future work is the comparison of our findings against other domains, such as scientific publication or wiki editing domains. That would provide an opportunity to generalize our results.

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10. REFERENCES

[1] The R project for statistical computing. `http://www.r-project.org/`, January 2013.

[2] J. Adler. *R in a Nutshell.* O'Reilly, second edition, 2012.

[3] K. Börner, N. Contractor, H. Falk-Krzesinski, S. Fiore, K. Hall, J. Keyton, B. Spring, D. Stokols, W. Trochim, and B. Uzzi. A multi-level systems perspective for the science of team science. *Science Translational Medicine*, 2(49), 2010.

[4] H. Cole and M. D. Griffiths. Social Interactions in Massively Multiplayer Online Role-Playing Gamers. *CyberPsychology & Behaviour*, 10(4), 2007.

[5] N. Contractor. Some assembly required: leveraging web science to understand and enable team assembly. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 371(1987), 2013.

[6] Curse, Inc. Dota 2 api wiki. `http://www.dota2wiki.com/wiki/API`, January 2013.

[7] Curse, Inc. Dota 2 wiki. `http://www.dota2wiki.com/wiki/Dota_2_Wiki`, January 2013.

[8] D. DiFranzo and A. Graves. A farm in every window: a study into the incentives for participation in the Windowfarm virtual community. In *Proceedings of ACM WebSci '11*, June 2011.

[9] Elo Entertainment, LLC. Dotabuff official website. `http://dotabuff.com/`, January 2013.

[10] K. Fisher and M. Fisher. *The distributed mind: Achieving high performance through the collective intelligence of knowledge work teams.* 1997.

[11] Forbes, LLC. Dota 2: "The International 2", and the future of e-sports. `http://www.forbes.com/sites/gregvoakes/2012/09/04/dota-2-the-international-2-and-the-future-of-esports/`, January 2013.

[12] J. Fox and S. Weisberg. *An R Companion to Applied Regression.* Sage Publications, second edition, 2011.

[13] G. Hofstede. *Culture's Consequences: International Differences in Work-Related Values.* Sage Publications, 1980.

[14] IGN. IGN People's choice award. http://www.ign.com/articles/2011/08/23/ign-peoples-choice-award-and-the-winner-is/, January 2013.

[15] M. Jacobs. Multiculturalism and cultural issues in online gaming communities. *Journal for Cultural Research*, 12(4):317–334, 2008.

[16] M. Kałuża and E. Golik. Intercultural communication and the Internet. The role of intercultural communication in Internet societies. *Informacios Mokslai*, 45:22–34, 2008.

[17] B. Keegan, M. A. Ahmed, D. Williams, J. Srivastava, and N. Contractor. Sic Transit Gloria Mundi Virtuali? Promise and Peril in the Computational Social Science of Clandestine Organizing. In *Proceedings of ACM WebSci '11*, June 2011.

[18] A. Kristof, K. Brown, H. Sims, and K. Smith. The virtual team: A case study and inductive model. *In M.Beyerlein & D. Johnsons (Eds), Advances in interdisciplinary studies of work teams: Knowledge teams the creative edge*, 2:229–253, 1995.

[19] L. Lee-Kelley and T. Sankey. Global virtual teams for value creation and project success: A case study. *International Journal of Project Management*, 26(1):51 – 62, 2008.

[20] V. Lehdonvirta. Virtual economics: Applying economics to the study of game worlds. In *Proceedings of the 2005 Conference on Future Play*, October 2005.

[21] B. Medler. Player Dossiers: Analyzing Gameplay Data as a Reward. *Game Studies Journal*, 2011.

[22] N. Pobiedina and J. Neidhardt and M.C. Calatrava Moreno and L. Grad-Gyenge and H. Werthner. On successful team formation. Technical report, Vienna University of Technology, 2013. Available at http://www.ec.tuwien.ac.at/files/OnSuccessfulTeamFormation.pdf.

[23] T. Nuangjumnong and H. Mitomob. Leadership Development Through Online Gaming. In *Proceedings of The 19th ITS Biennial Conference 2012*, November 2012.

[24] P. Zackariasson and N. Wåhlin and T.L. Wilson. Virtual identities and market segmentation in marketing in and throught massively multiplayer online games (MMOGs). *Services Marketing Quarterly*, 31(3):275–295, 2010.

[25] PC Gamer. The PC Gamer 2012 game of the year nominees. http://www.pcgamer.com/2012/12/11/pc-gamers-game-of-the-year-nominees/, January 2013.

[26] D. Pittman and C. GauthierDickey. A measurement study of virtual populations in massively multiplayer online games. In *Proceedings of the 6th ACM SIGCOMM workshop on Network and system support for games*, NetGames '07, pages 25–30, New York, NY, USA, 2007. ACM.

[27] V. Ratcheva and S. Vyakarnam. Exploring team formation processes in virtual partnerships. *Integrated Manufacturing Systems*, 12(7):512–523, 2001.

[28] O. Shenkar. Cultural distance revisited: Towards a more rigorous conceptualization and measurement of cultural differences. *J Int Bus Stud*, 32(3):519–535, 2001.

[29] K. J. Shim, N. Pathak, M. A. Ahmad, C. DeLong, Z. Borbora, A. Mahapatra, and J. Srivastava. Analyzing Human Behavior from Multiplayer Online Game Logs: A Knowledge Discovery Approach. *IEEE Intelligent Systems*, 26(1), 2011.

[30] A. M. Townsend, S. M. DeMarie, and A. R. Hendrickson. Virtual teams: Technology and the workplace of the future. *The Academy of Management Executive*, 12(3):17–29, 1998.

[31] Valve Corporation. Dota 2 - official blog. http://www.dota2.com/, January 2013.

[32] Valve Corporation. Dota 2 on steam. http://store.steampowered.com/app/570/, January 2013.

[33] Valve Corporation. Valve software. http://www.valvesoftware.com/, January 2013.

[34] Valve Developer Community. Steam web api. https://developer.valvesoftware.com/wiki/Steam_Web_API, January 2013.

[35] X. Zhuang and A. Bharambe and J. Pang and S. Seshan. Player Dynamics in Massively Multiplayer Online Games. http://reports-archive.adm.cs.cmu.edu/anon/2007/CMU-CS-07-158.pdf, October 2007.

[36] N. Yee. The Psychology of MMORPGs: Emotional Investment, Motivations, Relationship Formation, and Problematic Usage. *In R. Schroeder & A. Axelsson (Eds.), Avatars at work and play: collaboration and interaction in shared virtual environments*, pages 187–207, 2006.

[37] R. Yuan, L. Zhao, and W. Wang. Cooperation and competition dynamics in an online game community. In *Proceedings of the 2nd international conference on Online communities and social computing*, OCSC'07, pages 475–484, Berlin, Heidelberg, 2007. Springer-Verlag.