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Group Formation Theory at Multiple Scales

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Abstract. There is a wealth of psychological theory regarding the drive for individuals to congregate and form social groups, positing that people may organize out of fear, social pressure, or even to manage their self-esteem. We evaluate three such theories for multi-scale validity by studying them not only at the individual scale for which they were originally developed, but also for applicability to group interactions and behavior. We implement this multi-scale analysis using a dataset of communications and group membership derived from a long-running online game, matching the intent behind the theories to quantitative measures that describe players' behavior. Once we establish that the theories hold for the dataset, we increase the scope to test the theories at the higher scale of group interactions. Despite being formulated to describe individual cognition and motivation, we show that some group dynamics theories hold at the higher level of group cognition and can effectively describe the behavior of joint decision making and higher-level interactions.

Keywords: group dynamics · social networks · collective action · communication patterns · multi-scale dynamics · organizational theory · group behavior

1 Introduction

Emergent organization is a key characteristic of complex social systems, and as such, social science researchers have done significant work to understand how people organize themselves into groups [8, 1, 12]. However, the majority of this research has focused on the individual-scale, studying how and why people form and join groups with little attention paid to the dynamics at higher scales [22]. This individual focus, however, has left group-level interactions largely unexplained. A better understanding of how scalable various theories are provides

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information on the social dynamics and causal foundations behind group behavior, with broad applicability including terrorist group emergence, international alliances, protesting behavior, and scientific research communities.

This article addresses this problem by evaluating the hypothesis that cross-scale emergence of groups and recursive interactions have similarities at different scales. Emergent organization is fundamental to social system dynamics [10], where individuals with heterogeneous traits and behaviors organize themselves into groups with their own distinct characteristics and behaviors. These groups can exist at any scale, from a few individuals to collections of countries, and individuals can associate with many groups. Groups can influence individuals, interact with each other, and form groups of groups. The complexities of group dynamics influence group emergence, recursive interactions, and the multi-scale nature of these systems makes understanding them difficult, but by testing the hypothesis that different scales of group dynamics have similar tendencies, we can begin to evaluate whether the substantial social science research that has been done at the individual scale might also apply at higher scales, facilitating new investigation into these complex dynamics.

To this end, we study the data from a massively multiplayer online game (MMOG) that we will refer to as *Game X* [18], in which players can interact and join explicit groups called guilds. Using online gaming datasets to study social group dynamics is not uncommon for this type of research, with well documented benefits and drawbacks for social science research [6]. Examinations of online games have spanned from interviews with players to data-driven studies that build models to mimic the behavior observed in the game [24, 13]. Such studies have even extended to epidemiology and, most relevant to this work, the analysis of social ties between players [2, 7]. These studies leverage many of the benefits of using MMOGs as interesting social science test beds [14], allowing for the detailed observation of in-game behaviors that would be largely unobtainable from real-world social interactions. *Game X* is particularly useful for investigating the multi-scale potential of group formation theory because in addition to players interacting to form casual groups, the guild construct allows players to declare explicit groups that provide rich temporal data for study.

To investigate the multi-scale nature of group formation theory, we tested a set of existing theories, all of which were initially developed to explain group formation at the individual scale, on the dataset at both the individual and group levels. This analysis helps us to understand whether the data supports the selected theories in general, as well as whether the data suggests that the theories hold at higher scales. This analysis is an initial step in understanding whether multi-scale group dynamics theory is likely to exist, whether individual-level theory on group formation holds at the higher scale, and whether there are parts of the theory that hold better than others. Using this framework to guide our investigation, we show that some existing individual-level theory does hold at multiple scales, thus demonstrating that there is potential for multi-scale theory on group formation.

2 Testing Existing Theory at Multiple Scales

2.1 Dataset Description

The theories discussed in this work were chosen based on both their potential for applicability at multiple scales and their relevance to the game dataset, and then interpreted based on available data. We then tested these theories at both the individual level, looking at individuals joining groups, and the group level, looking at groups merging together into larger groups or decaying as they lose subgroups of their membership. All data on social interactions were derived from the *Game X* dataset, a game where players move in a 2-D world gathering resources, interacting with other players, and building infrastructure such as factories, market centers and cities. *Game X* is open-ended with no specified win conditions, and has been online for more than a decade with hundreds of players.

A key characteristic of this study is the ability of *Game X* players to organize themselves into guilds as player-led groups that have a private communication mechanism. In the game, players are not required to join guilds, and guild membership is entirely voluntary, although it does hold benefits. Guilds are a major part of the game and effectively function as quasi-states that control territory. Guilds can range in size from just 2 players to more than hundreds. Combat often erupts between guilds as they fight over access to resources, territory, differences in culture, or as retribution to actual or perceived slights. Additionally, trade is a central part of the game in order to build more advanced structures and vehicles, including multi-step supply chains involving numerous players that are often managed by guilds. This work uses a dataset encompassing a real-world time period of over 2 years, and contains information about player trade, combat, and communications.

Guild level events of particular interest in this paper include lifecycle events where the guild as a whole undergoes a significant change in its membership. These events fall into multiple categories that are mentioned throughout the paper: birth, death, growth, loss, and merge events. Birth and death events are simply defined as the moments the guild is officially created and disbanded within the game. Guilds always have contiguous lifespans and at least one member; if a guild collapses down to no members and the players wish to reform later, they must form a new independent guild via a new guild birth event. Additionally, players are free to join and leave guilds at any point, and a guild can die simply from all of its members joining other guilds or choosing to be independent. In contrast, growth and loss events are interpreted based on periods of time with abnormal change in membership for guilds. For this work, we analyze two week long time windows, defining an abnormal period as gross gain or loss of members greater than two standard deviations from the mean value for all possible guilds over all possible time windows. Abnormal periods are then filtered such that no growth or loss events overlap with each other. Finally, merge events are a subset of growth and loss events where at least on quarter of players involved in the event all join or originate from the same guild within the two week period

following/preceding the event. For example, if twelve players leave Guild A at once (qualifying as a loss event) and four of those players all join Guild B within two weeks, then it would also be categorized as a merge event. Likewise if twelve players join Guild B and four of them come from Guild A then it also qualifies as a merge event.

2.2 Group Cohesiveness

Group cohesiveness theory says that people in highly cohesive groups are motivated to stay in those groups, and to contribute to and advance the group as a whole [5]. This in turn contributes to the group's potency and vitality, leading to healthier groups and greater longevity. Further, it has been theorized that as groups survive longer they become more cohesive, manifesting an increasing density and shrinking average distance over time between members [19]. We considered cohesiveness in the *Game X* dataset to be based on the social network defined by communication frequency between players. We developed this network using a 7-day window of messaging between players; for a given time record x, two nodes u and v have an edge between them of weight w, where w is the raw number of communications between nodes u and v in the time window $t = [x - 7, x]$. To define distance between nodes, we used the normalized inverse weight, $d_{u,v} = w_{avg}/w_{u,v}$, such that the distance between nodes reflects the closeness of the relationship relative to all other relationships in the network.

Using this representation, we determined cohesiveness of social networks by calculating the normalized harmonic closeness centrality, a measure of how close each node is to every other node in the network. The normalized harmonic centrality is calculated for a node u as

$$H(u) = \frac{1}{N-1} \sum_{u \neq v} \frac{1}{d_{u,v}} \tag{1}$$

where N is the total number of nodes in the network [21, 20]. We used this value as a measure for how deeply ingrained individuals are within their social networks, and the average normalized centrality to measure of how dense the network is at critical points.

The theory of group cohesiveness suggests that healthier guilds have higher average centralities, and that individuals with higher centrality within their respective guilds are more socially ingrained and thus less likely to leave. We began testing this theory by comparing the average centrality of individuals in guilds that are undergoing no guild changes (our control group) to those in the week before they leave their guild (either to remain independent or to join another guild). Indeed, Table 1 shows that guild members about to leave their guilds have lower average centrality than those who are stable in their guilds, supporting the theory of group cohesiveness at the individual scale. Interestingly, guilds undergoing loss events show similar drops in average centrality across the guild. This average centrality is calculated guild wide, including players that remain in the guild after the event. When narrowed to merge events the average

centrality drops even further. This suggests that not only are the individuals leaving guilds less connected to their neighbors than those in stable guild membership situations, but guilds as a whole become less centralized as they near periods of instability. The above results intuitively confirms group cohesiveness

Table 1. Centrality values for guilds undergoing different life cycle events and how they differ from a stable guild. tables.

	Average Centrality	**Difference from Healthy Guild**
Stable Guild	0.70	N/A
Guild Change	0.55	21%
Loss Event	0.57	19%
Merge Event	0.51	28%

theory as an indicator of guild stability on the individual level, leading to further investigation into the multiscale validity of the theory. To this end, we study a higher level in-game social network where the nodes are groups, and ties between them are messages sent by any member of one group to any member of another. This guild-to-guild network represents the positions of guilds within the overall context of the game. Messaging rates between guilds are chosen over other guild-level connections for consistency with the individual level analysis above to facilitate the comparison. In this formulation, a guild leaving the network is analogous to a guild dying out entirely, while large-scale loss events represent guilds that are able to survive sudden drops in membership. Using these events as our focus times, we found that the average guild to guild centrality across all guilds in the network holds fairly steady across timesteps at $H_{avg} = 0.44$, while the centrality of guilds preceding a death event reaches $H_{death} = 0.32$ at its minimum and $H_{death} = 0.39$ in the final time step before the event. Guilds undergoing loss events that don't lead to their deaths, however, actually show a spike in guild to guild centrality up to a maximum of $H_{loss} = 0.66$ in the final timestep before the event. This is partially explained by players leaving during these loss events messaging other guilds to find new groups to join; however, looking at longer time horizons reveals further nuance. Fig. 1 demonstrates that while guilds do see a drop in centrality before death and a growth in centrality before loss events, this is part of an overall trend where dying guilds have lower stable centrality than average, while those that survive their loss events have a higher stable average centrality. This phenomenon fits well with group cohesiveness theory, in that guilds that are more central to the *Game X* social network are a part of a healthier subsystem and are thus more resilient to sudden losses of players, while those that are less central find themselves leaving the system entirely when facing a large exodus of players.

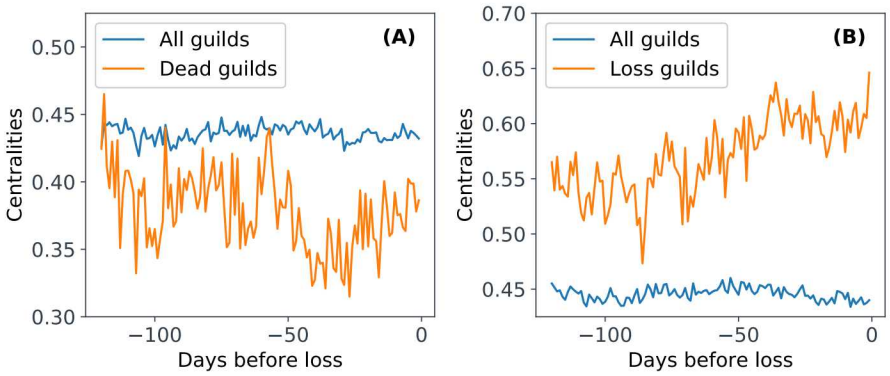

Fig. 1. Average centrality of guilds 120 days before they undergo (a) death and (b) loss events compared to the average centralities across all guilds at the same times.

2.3 Sociometer Theory

Sociometer theory relates the self-esteem of individuals and their social connectedness, measuring social health within a group using social inclusion and risk of rejection [17]. The theory asserts that the self-esteem, or lack thereof, that people feel in relation to a group is a measure of their perceived social exclusion and perceived potential for rejection from that group. Further, sociometer theory relates feelings of belonging to their evaluation of relationships between themselves and others, with negative relational evaluations negatively impacting an individual's perceived social position [16]. Since the theory asserts that an individual's self-esteem can be measured based on the perceived likelihood that the individual will be accepted and included in a social setting [15], we relate the likelihood of changing social settings to individuals' confidence that they will be accepted. For the purposes of this paper we measure this based on messaging rates prior to joining a new guild, assuming that individuals and groups with higher relative self-esteem will need less engagement with their new group as reassurance before making the decision to officially join.

For this analysis, we considered the individual scale by looking at communication rates during the week in which a person joined a group or changed groups, and compared those to communication rates at all other times. We also considered with whom individuals were communicating, specifically evaluating communication with people in guilds the individual was preparing to join compared to communication rates with others. For all of these analyses, we consider the directionality of the messages to identify any reciprocity disparities. Using this data, we compare baseline communication activity to the communications leading up to the individual joining a new social group, identifying patterns that suggest social inclusiveness prior to an individual joining or changing guilds. As shown in Table 2, we found a strong relationship between volume of messages and group dynamics, but no strong relationship regarding reciprocity. In

particular, individuals that have never joined a guild before exhibit very high messaging activity towards the group they plan to join; four times the messaging rate to individuals in other guilds or no guilds. This fits with sociometer theory's assertion that group and personal relationships are driven by self-esteem of the individuals, indicating that new players need the most assurance that they will fit in and not be rejected by a new guild before joining. These are the players that would be expected to have the lowest self-esteem, thus needing strong relational evaluations before feeling confident in their fit with a group. The trend also holds for players changing guilds, but it is muted at around a fifty percent increase, further fitting with the hypothesis that players with more experience in guild and social dynamics require less communication before committing to a new guild. To expand this analysis to the group scale, we considered messag-

Table 2. Number of messages sent by individuals in the week before changes in their guild membership.

	With player in					
	Accepting Guild		**Other Guild**		**No Guild**	
	In	Out	In	Out	In	Out
Joining new guild	2.2	2.2	0.5	0.6	0.6	0.7
Changing guilds	1.6	1.6	1.1	1.2	0.2	0.3
No guild change	0.9	0.9	0.6	0.6	0.1	0.1

ing within and between the guilds in *Game X* during times of merge events. We considered mean messages per person in the sub-group of individuals that moved from one guild to another for the month surrounding a merge event. This messages-per-person metric was chosen to control for the size of the sub-group, and we considered a one-month period to capture communication dynamics both before and after the period of player movement. The results, contained in Table 3, show a large amount of communication between the individuals leaving a guild and other individuals inside that guild, mostly involving other leaving members. There is, however, only a small number of messages sent and received by the new guild that the players are moving to, indicating that guild merge events do not have the same consideration period noted for individual player movements. Movement of players within these subgroups does not appear to require establishment of a relationship with the new social group; instead we see a strengthening of bonds and increased communication within the sub-group itself. This suggests that the sociometric effect on self-esteem is not a factor driving guild merge events (or at least in the choice of receiving guild). Instead, the data indicates that the sub-group players have positive group self-esteem through their sense of belonging within the sub-group, and are thus unafraid of rejection in the new larger guild they join together. As a result, using this behavior as a sociometric evaluation for the likelihood of movement at the group-level fails, despite its high correlation at the individual level.

Table 3. Messages sent by players within the sub-group of individuals leaving one guild for another compared to the overall rates of the sending and receiving guilds.

	Messages Prior to Merge	
	In	Out
Sub Group	1.67	1.67
Loss Guild	2.43	2.35
Receiving Guild	0.24	0.23

2.4 Terror Management Theory and Mortality Salience

Terror management theory [9, 23] posits that anxiety over death, caused by the conflict between a person's self-preservation instinct and their knowledge of the inevitability of death, causes humans to seek cultural identity in a variety of ways, one of which is group membership [11]. According to the related mortality salience hypothesis [4], being reminded of one's own mortality enhances these behaviors. We test these theories on individual-level group dynamics in the *Game X* dataset by studying the death rate of players in the days before they chose to join a new guild compared to baseline death rates. Game death in *Game X* consists of a player's character "dying", leading the character to lose skills (temporarily) and equipment (permanently) in the game. We assert that due to the emotional investment, salient experiences, and high degree of social value and support that players derive from role playing games [3, 25], game death increases mortality salience by serving as a reminder of death and loss and thus allows us to test the impact of terror management theory within the game. The time windows before players joined guilds were chosen to be those with the highest rate of deaths per day over the window, yielding windows of 2 days before merge events for guilds and 1 day before guild changes for individuals. The resulting pre-event death rates are shown in Fig. 2(a), where in the day before a player joins a new guild, the average number of deaths per day was 0.1005 while over all other times the average number of deaths per day was 0.0069, revealing a pre-event death rate 14.6 times higher than the baseline that indicates a high level of correlation between individual player death and the decision to join a new guild.

At the group level, we used a similar analysis to evaluate the number of deaths per day in a guild before that guild underwent a merge event. As shown in Fig. 2(b), on the day before such a merge event, the average number of deaths per day was 1.914, while over all other times this value was only 0.518. Thus, at the group level deaths were 3.7 times higher than the baseline. This relationship did not hold for the receiving guild, where there was no increase in the deaths per day in the days leading up to receiving the influx of players, indicating that death is only a driving factor in leaving and joining guilds, not guilds recruiting new players from others. Despite the relative rarity of group-level events and the generally more slowly moving dynamics, this result shows a high level of time-separated correlation between deaths and group dynamics, and indicates

that the mortality that drives many individuals to join groups in the first place can also push a group as a whole to find other groups with which to combine.

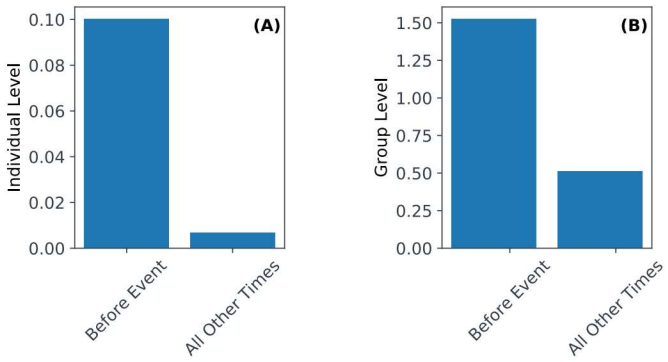

Fig. 2. Deaths per day at the (a) individual and (b) group levels before guild change or merge events as opposed to all other times.

3 Conclusions

Increasing online social interaction has presented new opportunities to study how people behave in natural settings, providing large-scale datasets with troves of valuable information. By using data from *Game X* to test and expand social theory about what drives individuals into groups, we investigate the potential for theories of individual behavior to hold at higher scales in which groups interact with each other as their own entities. Throughout our analysis we find that, in most cases, groups as a whole do behave similarly to the individuals that make them up. This is most directly evident for terror management theory, where the data had simple and direct approximations of death, but also holds for the theory of group cohesiveness where we show that both groups and individuals on the fringes of their respective networks are at greater risk for leaving the network entirely. In contrast, while we show that while sociometric pressures influence behavior at the individual level, they do not manifest in the same way at the group level.

These results provide evidence that some social theories, despite being formulated with individual cognition and behavior in mind, will hold at multiple scales and describe the behavior of both individuals and groups. Not all theories have this scalability, as some key in on inherently individual aspects of cognition such as self-esteem, but these exceptions simply provide further incentive to continue testing social and psychological theory at multiple scales. In doing so we can not only learn how well the given theory holds, but also gain insight

into how groups think, behave, and come to collective decisions. For this reason, future work should consider not only other theories on group behavior, but also how scaled actions for collections of people come about, how group sizes affect the decision-making ability of a group, and how far the scalability holds in the presence of multi-hierarchical group dynamics.

References

1. Backstrom, L., Huttenlocher, D., Kleinberg, J., Lan, X.: Group formation in large social networks: membership, growth, and evolution. In: Proceedings of the 12th ACM SIGKDD. pp. 44–54 (2006)
2. Balicer, R.D.: Modeling Infectious Diseases Dissemination Through Online Role-Playing Games. Epidemiology **18**(2), 260–261 (mar 2007)
3. Barnett, J., Coulson, M.: Virtually real: A psychological perspective on massively multiplayer online games. Rev of Gen Psych **14**(2), 167–179 (2010)
4. Burke, B.L., Martens, A., Faucher, E.H.: Two decades of terror management theory: A meta-analysis of mortality salience research. Pers Soc Psychol Rev **14**(2), 155–195 (2010)
5. Cartwright, D., Zander, A.: Group dynamics, 3rd ed. Group dynamics, 3rd ed, Harper + Row, Oxford, England (1968), pages: 580
6. Ducheneaut, N.: Massively Multiplayer Online Games as Living Laboratories: Opportunities and Pitfalls. pp. 135–145. Springer, London (2010)
7. Ducheneaut, N., Yee, N., Nickell, E., Moore, R.: The Life and Death of Online Gaming Communities: A Look at Guilds in World of Warcraft. In: SIGCHI. pp. 839–848 (2007)
8. Forsyth, D.R.: Group dynamics. Cengage Learning (2018)
9. Greenberg, J., Pyszczynski, T., Solomon, S.: The causes and consequences of a need for self-esteem: A terror management theory. In: Public self and private self, pp. 189–212. Springer (1986)
10. Helbing, D., Yu, W., Rauhut, H.: Self-organization and emergence in social systems: Modeling the coevolution of social environments and cooperative behavior. J Math Sociol **35**(1-3), 177–208 (2011)
11. Hogg, M.A., Hohman, Z.P., Rivera, J.E.: Why do people join groups? Three motivational accounts from social psychology. Social and Personality Psychology Compass **2**(3), 1269–1280 (2008)
12. Hogg, M.A., Turner, J.C.: Interpersonal attraction, social identification and psychological group formation. Eur J Soc Psychol **15**(1), 51–66 (1985)
13. Johnson, N.F., Xu, C., Zhao, Z., Ducheneaut, N., Yee, N., Tita, G., Hui, P.M.: Human group formation in online guilds and offline gangs driven by a common team dynamic. Phys Rev E **79**(6), 066117 (jun 2009)
14. Lakkaraju, K., Epifanovskaya, L.W.E., Stites, M.C., Letchford, J., Reinhardt, J.C., Whetzel, J.: Online Games for Studying Human Behavior. Tech. rep., Sandia National Lab.(SNL-NM), Albuquerque, NM (United States); Sandia … (2018)
15. Leary, M.R.: Sociometer theory and the pursuit of relational value: Getting to the root of self-esteem. Eur Rev of Soc Psychol **16**(1), 75–111 (Jan 2005)
16. Leary, M.R., Baumeister, R.F.: The nature and function of self-esteem: Sociometer theory. In: Advances in Experimental Social Psychology, vol. 32, pp. 1–62. Academic Press (Jan 2000)

17. Leary, M.R., Downs, D.L.: Interpersonal Functions of the Self-Esteem Motive. In: Kernis, M.H. (ed.) Efficacy, Agency, and Self-Esteem, pp. 123–144. The Springer Series in Social Clinical Psychology, Springer US, Boston, MA (1995)
18. Lee, J., Lakkaraju, K.: Predicting Social Ties in Massively Multiplayer Online Games. In: International Conference on Social Computing, Behavioral-Cultural Modeling, and Prediction. pp. 95–102. Springer (2014)
19. Leskovec, J., Kleinberg, J., Faloutsos, C.: Graphs over time: densification laws, shrinking diameters and possible explanations. In: ACM SIGKDD. pp. 177–187. KDD '05, Association for Computing Machinery, Chicago, Illinois, USA (Aug 2005)
20. Marchiori, M., Latora, V.: Harmony in the small-world. Physica A **285**(3), 539–546 (Oct 2000)
21. Rochat, Y.: Closeness centrality extended to unconnected graphs: The harmonic centrality index. Tech. rep., Institute of Applied Mathematics, University of Lausanne (2009)
22. Smaldino, P., Pickett, C., Sherman, J., Schank, J.: An agent-based model of social identity dynamics. JASSS **15**(4), 7 (2012)
23. Solomon, S., Greenberg, J., Pyszczynski, T.: The worm at the core: On the role of death in life. Random House (2015)
24. Williams, D., Ducheneaut, N., Xiong, L., Zhang, Y., Yee, N., Nickell, E.: From Tree House to Barracks. Games and Culture **1**(4), 338–361 (oct 2006)
25. Yee, N.: The psychology of massively multi-user online role-playing games: Motivations, emotional investment, relationships and problematic usage. In: Avatars at work and play, pp. 187–207. Springer (2006)