WoW!: The Co-evolution of Communication Networks and Perceived Expertise in a Massively Multiplayer Online Role Playing Game

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WoW! Outline

- Introduce WoW
- Theoretical Background
- MCMC Background
- Data Overview
- Modeling Results
- Conclusions
- Extensions*
Rise of ‘World of Warcraft’

Source: http://www.mmogchart.com/
Research Issues

This study examines the dynamic co-evolution of group members’ perceived expertise (an attribute) and their intra-group communication (a network).

1. How does communication network structure evolve over time?
2. How does perceived expertise influence the communication network over time?
3. How does a communication network influence perceived expertise over time?
4. How do the communication network and perceived expertise co-evolve over time?
<table>
<thead>
<tr>
<th></th>
<th>Human A</th>
<th>Human B</th>
<th>Human C</th>
<th>Non Human Agent X</th>
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* e.g., *Smart Mobs*
## Contextualizing Goals of Communities

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<td>Emergency Response Community</td>
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<td>WoW Gaming Community</td>
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<td>PackEdge Communities of Practice</td>
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<td>Economic Resilience NGO Community</td>
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<td>Tobacco Surveillance, Evaluation &amp; Epidemiology Community</td>
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<td>Environmental Engineering Community</td>
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A “meta-theory” of social drivers for creating, sustaining, and dissolving networks

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<td>Theories of Homophily</td>
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<td>Theories of Proximity</td>
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What Have We Learned About These Network Mechanisms?

- Research typically looks at only one of these mechanisms.
- The outcomes of these mechanisms often contradict one another.
- Some mechanisms are studied more often than others.
- Most research examines these mechanisms at one point in time.
Enter ERGM Framework

- Integrating exogenous and endogenous processes based on multiple theories at multiple levels leads to many possible realizations of the network.
- The observed network is one realization of the many possible realizations of the network.
- Confirmatory Network Analysis: The question of interest in statistical modeling is whether the observed network exhibits the theoretically hypothesized structural tendencies.
Methods and Analysis

• **SIENA**
  Simulation Investigation for Empirical Network Analysis

• statistical estimation of models for longitudinal social networks according to the dynamic, actor-oriented model of Snijders and van Duijn (1997), Snijders (2001), and Snijders (2005).

Dynamic Actor-Oriented Model

- The main assumption of this type of modeling is that actors have control of outgoing ties.
- Continuous-time Markov models seem to be the best at analyzing panel data. They assume that the network was continuously changing but we only get snapshots of the network.
- Probabilistic framework combines Markov processes with random utility modeling.
- Snijders (1996, 2001)
Score Tests

- Currently these are the only Goodness of Fit tests available
  - Schweinberger (2005)
- Based on Method of Moment Estimators (not likelihood ratios)
- Generalized Neyman-Rao Score tests
- Still in development
Participants

- Longitudinal survey data were collected from a Massively Multiplayer Online Role-Playing Game (World of Warcraft).
- Teams perform diverse quests within the game environment, typically varying in length from one hour to several days, with the goal of achieving an objective, gaining resources, and increasing experience.
- Players belong to a guild (a group of people able to answer questions, etc.)
- Guilds in the program ranged in size from 8 to 17. Members are predominantly male (78.5%) and white (90%). Guild members ranged in age from 16 to 63 (M = 25.99 years, SD = 7.48).
Classes of Characters

- **Warrior** - master of weapons and close combat. They are the most durable class in a fight.

- **Mage** - commands the elements of fire and frost to produce some of the most destructive spells in combat, but is very fragile when directly confronted.

- **Shaman** - a spiritual class that is well-rounded in terms of magical and combat powers. They can heal or enhance friendly players, use offensive magic, and attack effectively with weapons.

- **Hunter** - master of beasts and ranged combat. Hunters can tame wild beasts and use them effectively in combat, as well as inflict damage from afar with bows or guns.

- **Warlock** - mages who have become too immersed in demonic power. They call upon chaotic magics to inflict slow pain on enemies and summon demons to do their bidding.

- **Druid** - master of the forces of nature. Druids can use shapeshifting magic to perform different roles in a group as needed.

- **Paladin** - holy warriors who have access to healing and protective magics.

- **Rogue** - master of stealth and surprise. Rogues are useful for their stealth tactics, poisons, and proficiency in combat.

- **Priest** - master of holy and shadow magics. Priests are the most effective healers, and are necessary in any good group. When needed, they can call upon shadow magic to add some force in battle as well.
Data collection

- Data were collected from 8 guilds (N=11, 11, 8, 8, 8, 8, 17, 8) at 3 points in time.
  - T1: initial contact and survey administration
  - T2: two weeks after initial survey administration
  - T3: four weeks after initial survey administration
- Demographic information:
  - Gender:
    - 17 female members (21.5%)
    - 62 male members (78.5%)
  - Ethnicity:
    - 71 Caucasian (89.9%)
    - 4 Asian (5.1%)
    - 1 African American (1.3%)
    - 2 Hispanic/Latino (2.5%)
    - 1 Native American (1.3%)
Perceived Expertise

Summary measure of each guild members’ expertise made by all other guild members (including themselves)

Question:

- The world of ‘World of Warcraft’ is vast and complicated and people often find that they need to ask each other questions. In the following section we want to know who knows what in your guild. This question is asking who knows the most, which may or may not be the same as who you actually ask. Pick one or two people. You may pick yourself.

1. How the Game works
2. Quests
3. Blacksmithing
4. Enchanting
5. Leatherworking
6. Your Character’s Class
Your Character’s Class

Your class (Warrior, rogue, mage, etc.), for the character you play the most, e.g. how to use talent points and abilities, class quests and balance issues, etc.? Pick ONE OR TWO people You can pick yourself.
Collecting this information was intended to have a network measure of perceived expertise.

By restricting the number of people that participants can nominate, the main assumption of the actor-oriented model.

We transformed this measure into an attribute, perceived expertise.
Communication/Advice Network

Communication networks

“How often do you ask <guildmember> for WoW advice or information?” (CRI)

Measurement:

*All the time, Often, Sometimes, Rarely, Never*

Transformed:

Rarely – Never = 0

All the time – Sometimes = 1
Expertise/Information Retrieval Time Two
Expertise/Information Retrieval Time Three
Network Density Plots
Model One: Structural Factors

- **Social Exchange Theory**: Individuals are more likely to reciprocate communication ties with those who have created ties with them previously.
  - Reciprocity/Mutuality

- **Balance Theory**: Individuals are more likely to create ties with people their contacts communicate with.
  - Balance
  - Transitivity
  - Actors at Distance Two
Impact of Structural and Behavioral Factors

- **Cognition**: Individuals assess the attribute of others and the network between others.
  - Correlation of expertise attributions across members

- **Homophily**: Individuals are more likely to have similar levels of perceived expertise to those members of team with whom they have ties.
  - Expertise similarity
  - Expertise alter
  - Expertise tendency

- **Proximity**: Individuals are more likely to share guilds with those who are more physically proximate
  - Correlation of guild memberships and proximity
Model Two: Structural and Behavioral Factors

- **Social Exchange Theory:** Individuals are more likely to reciprocate communication ties with those who have created ties with them previously.
  - Reciprocity/Mutuality

- **Balance Theory:** Individuals are more likely to create ties with people their contacts communicate with.
  - Balance
  - Transitivity
  - Actors at Distance Two

- **Homophily:** Individuals are more likely to have similar levels of perceived expertise to those members of team with who they have ties.
  - Expertise similarity
  - Expertise alter
  - Expertise tendency

- **Rates of Change:** Cognitive and structural attributes may not change at the same rate.
  - Estimate rate parameters for time steps
Model 1

- Initial test for dyadic independence.
- Use score tests to determine if including dyadic and triadic effects significantly improve the model.
- Does adding structural components improve the model?
### Analysis Results: Model 1 – Evolution of Network Structure

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>Convergence t-statistic</th>
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</thead>
<tbody>
<tr>
<td>Density (out-degree)</td>
<td>-1.29</td>
<td>0.11</td>
<td>0.012</td>
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<tr>
<td>Reciprocity</td>
<td>0.28</td>
<td>0.14</td>
<td>-0.005</td>
</tr>
<tr>
<td>Transitive Triplets</td>
<td>0.13</td>
<td>(0.02)</td>
<td></td>
</tr>
<tr>
<td>Balance</td>
<td>5.16</td>
<td>(2.1)</td>
<td></td>
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</tbody>
</table>

*All significant at 0.05 level*

*Joint Score Test for transitive triplets and balance*

- **C=6.61 df=2 p-value = 0.0367**
- **Only transitive triplets c=1.47 df=1 p=0.22**
- **Only balance c=5.51 df=1 p=0.01**
Analysis Results: Model 1 – Evolution of Network Structure

- Guild members tend NOT to ask for advice from other guild members over time.
- Guild members tend to reciprocate advice ties with other members over time. (*social exchange*)
- Guild members tend to get advice from the person who gives advice to the person they ask for advice over time. (*balance, transitivity*)
Model 2- Co-evolution of network structure and behavioral attributes

- Includes all structural properties found in Model 1
- Adds other ‘homophily’ measures
  - Actor similarity
- Model how perceived expertise and asking for advice influence each other.
Analysis Results: Model 2- Co-evolution of network structure and behavioral attributes

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<tr>
<td>Density (out-degree)</td>
<td>-1.71</td>
<td>0.17</td>
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<tr>
<td>Reciprocity</td>
<td>0.38</td>
<td>0.14</td>
</tr>
<tr>
<td>Transitive Triples</td>
<td>0.15</td>
<td>0.02</td>
</tr>
<tr>
<td>Perceived Expertise Similarity</td>
<td>0.80</td>
<td>0.47</td>
</tr>
<tr>
<td>Perceived Expertise Alter</td>
<td>0.06</td>
<td>0.02</td>
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<tr>
<td>Constant Network Rate (period 1)</td>
<td>1.29</td>
<td>0.12</td>
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<tr>
<td>Constant Network Rate (period 2)</td>
<td>1.30</td>
<td>0.12</td>
</tr>
<tr>
<td>Perceived Expertise tendency</td>
<td>-0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Rate expc (period 1)</td>
<td>3.85</td>
<td>0.24</td>
</tr>
<tr>
<td>Rate expc (period 2)</td>
<td>3.10</td>
<td>0.18</td>
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</tbody>
</table>
Analysis Results: Model 2 – Co-evolution of Structure and Behavior

- Guild members tend NOT to ask for advice from other guild members over time.
- Guild members tend to reciprocate advice ties with other members over time. (*social exchange*)
- Guild members tend to be ask for advice from who the person who they ask for advice, asks for advice over time. (*balance, transitive triplets*)

(Time 1)  

(Time 2)
Analysis Results: Model 2 – Co-evolution of Structure and Behavior

- Guild members evaluate the expertise of potential alters before initiating or deleting ties.
- Network structure changes at a constant rate.
- Perceived expertise measures change more in the first time step than they do in the second.

![Diagram showing changes over time]
Why are these findings cool?

- Replicates previous findings in real time work groups
- Incorporates changes over time
- People seem to behave in similar ways in the virtual world and in the real world.
- Support the use of a virtual world for training, evaluation, etc.
What We Know So Far

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What more can be done with this data?

- Still have a lot of available networks and attributes to investigate.
- Can extend to different types of communication, friendship, closeness, etc.
- Could investigate networks composed of multiple networks
  - Pip, Garry, etc.
Treatment vs. Control

- Treatment groups (team 5, 6, 7, and 8) received a headset which allowed them to actually talk (Voice over Internet Protocol - VoIP)
- Control groups did not use VoIP (only text).
- Compare the networks of teams 1-4 and teams 5-8 to see if they evolve differently.
- Control = red  Treatment = blue
Expertise/Information Retrieval Time Three
### Treatment vs. Control

<table>
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<tr>
<th>Parameter</th>
<th>Control Estimate (se)</th>
<th>Treatment Estimate (se)</th>
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<tbody>
<tr>
<td>Density</td>
<td>-1.07 (0.16)</td>
<td>-1.07 (0.20)</td>
</tr>
<tr>
<td>Reciprocity</td>
<td>0.39 (0.21)</td>
<td>0.37 (0.18)</td>
</tr>
<tr>
<td>Transitive Triplets</td>
<td>0.09 (0.03)</td>
<td>-0.01 (0.02)</td>
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<tr>
<td>Actors at Distance Two</td>
<td>-0.39 (0.20)</td>
<td>-1.22 (0.23)</td>
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The main difference seems to be in “actors at distance two” effect…
Theoretical & Analytical Issues

- Additional analysis using approximately 30 more guilds and 10 more network relations associated with World of Warcraft.

- Cognitive mechanisms and proximity mechanisms remain to be investigated.

- Additional theoretical mechanisms: contagion by structural equivalence (influence), theories of collective action (selection).

- Time scale for “behavioral” changes may be different than for network structures.
Questions??
Comments on Data

• The data must be BINARY.
• The data are directed.
• Currently, only one dependent network can be specified.
• Can use multiple attributes
  – changing over time (age, gpa)
  – static (gender).
Assumption 1

• MARKOV ASSUMPTION: Changes in network ties and behavior happen in continuous time, at stochastically determined discrete moments, and the total difference between two consecutive observations is the result of many unobserved changes that occur between these observation moments.
Assumption 2

- Assumption 2: The possibility of simultaneous changes by two or more actors has probability zero.

- At any given moments, all actors act conditionally independently of each other given the current state of the process.
Assumption 3

- Assumption 3: Simultaneous changes in network ties and actor behavior have probability zero.
- Given the current state of the process, the changes which an actor applies to his/her network ties and changes made about his/her behavioral characteristics are all conditionally independent of each other.
Assumption 4

• Assumption 4: A change by an actor is the creation of one outgoing tie, the dissolution of one outgoing tie, or an increase or decrease in one behavior variable by one unit.

• Larger changes are modeled as the result of several small steps.
SIENA

• Step 1: Specify network(s) and attribute(s).
• Step 2: Specify model.
• Step 3: Estimate model.
  – Stage 1: estimate parameters
  – Stage 2: estimate standard errors
  – Stage 3: find residuals
Note about modeling...

- Must use forward model selection
- Problems with convergence when models become complex
- Estimation time is strongly related to model complexity.
- SIENA is robust to about 10% missing data.
We are modeling the effects of structural and behavioral properties

Structural Properties
• Balance
• Reciprocity/Mutuality
• Transitivity
• Actors at Distance Two
• Collective Activity

Behavioral Properties
• Cognition
• Exchange
• Homophily
• Proximity
Balance

• Focuses on **dyadic** and **triadic** relationships
• Heider (1946) “In the case of two entities, a balanced state exists if the relational ties between them are positive (or negative) in all aspects… In the case of three entities, a balanced state exists if all three possible relational ties are positive in all respects, or if two are negative and one is positive.”
• Ex- a friend of a friend is my friend.
Reciprocity/Mutuality

• Dyadic level
• A mutual tie exists between actor i and actor j.
• To test for a reciprocity effect, condition on the outdegree distribution of the actors. Randomly generate matrices with this outdegree distribution and compare the observed number of mutual ties with the simulated number of mutual ties.
• $S_{i2}(x) = \sum_j x_{ij}x_{ji}$
Transitivity

- Triadic level
- A relation is transitive if: when \( iRj \) and \( jRk \), then \( iRk \) for all \( i, j, \) and \( k \).
- In other words, if Bill chooses Joan and Joan chooses Kenny then Bill will choose Kenny.
- \( S_{i3}(x) = \sum_{j, h} x_{ij} x_{ih} x_{jh} \)
Actors at (Geodesic) Distance Two

• Triadic level

• A geodesic path of distance two exists between two actors when the shortest path between them contains only two edges

• If this measure is decreasing, the number of actors at distance two decreases, indicating more triad closure.

• $S_{i4}(x) = \#\{ j \mid x_{ij} = 0, \max_h(x_{ih}x_{hj}) > 0 \}$

• Identified as potentially the “best” measure of triadic closure.
Collective Activity

- Actors all participate in an event at the same time to gain outcomes that benefit all
- Hypergraphic attributes can be estimated via projections into the actor space
- Collective action is suggested by cohesive subgroups
  - Cliques
- Currently, higher-order structural aspects cannot be investigated with SIENA
  - Pnet
  - Statnet
Cognition

• “Who thinks who knows/does what”
• Ex.- perceived expertise
• With panel data we can evaluate similarity of perceptions over time
• If structures evolve as a result of cognitive information, there is support for theories of cognition
Exchange

• “You scratch my back, I’ll scratch yours”
• If you provide information to me at time one, I provide information to you at later time points
• Combines mutuality, balance and cognitive structures
• If perceived expertise, mutuality and balance co-evolve, there is evidence for theories of exchange
Homophily

• “Birds of a feather flock together”
• Ex- people with similar attributes will have similar patterns of relational ties
• Basic mechanism for network structure and actor attributes to influence one another.
• If reciprocal/mutual structures co-evolve with expertise similarity, there is evidence for theories of homophily
Proximity

• Geographic location is related to social structures
• Though WoW is a virtual environment, guilds may be constrained to friends who live in the same city
• If structural properties of guilds are correlated with geographic information, there is support for theories of proximity
# Seven Families of Social Science Theories and their Theoretical Mechanisms

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<th>Theoretical Mechanisms</th>
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<tbody>
<tr>
<td><strong>Theories of Self-Interest</strong></td>
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<tr>
<td>Social Capital</td>
<td>Maximization of individual benefits</td>
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<td>Structural Holes</td>
<td>Profit from Investment opportunities</td>
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<td>Transaction Costs</td>
<td>Control of information flow</td>
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<td><strong>Collective Action</strong></td>
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<tr>
<td>Public Goods Theory</td>
<td>Joint value maximization</td>
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<td>Critical Mass Theory</td>
<td>Inducements to contribute</td>
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<td>People with resources &amp; interests</td>
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<td><strong>Cognitive Theories</strong></td>
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<td>Semantic/knowledge Networks</td>
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<td>Drive to reduce dissonance</td>
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# Seven Families of Social Science Theories and their Theoretical Mechanisms, Con’t.

<table>
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<tr>
<td><strong>Contagion Theories</strong></td>
<td>Exposure to contact leading to infection:</td>
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<td>Social Information Processing</td>
<td>Social Influence</td>
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<tr>
<td>Social Learning Theory</td>
<td>Imitation and modeling</td>
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<tr>
<td>Institutional Theory</td>
<td>Mimetic behavior</td>
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<td>Structural Theory of Action</td>
<td>Similarity positions in structure &amp; roles</td>
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<td><strong>Exchange and Dependency Theories</strong></td>
<td>Exchange of valued resources</td>
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<tr>
<td>Social Exchange</td>
<td>Equality of exchange</td>
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<td>Resource Dependency</td>
<td>Inequality of exchange</td>
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<td>Network Exchange</td>
<td>Complex calculi for exchange balance</td>
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<td><strong>Homophily &amp; Proximity</strong></td>
<td>Choices based on similarity</td>
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<td>Social Comparison Theory</td>
<td>Communicate with comparable others</td>
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<td>Social Identity Theory</td>
<td>Choose others based on own group identity</td>
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<tr>
<td>Physical and Electronic Proximity</td>
<td>Influence of distance and accessibility</td>
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<td>Theory Families</td>
<td>Theoretical Mechanisms</td>
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<tr>
<td>Theories of Network Evolution</td>
<td>Variation, selection, retention</td>
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<td>Organizational Ecology</td>
<td>Competition for scarce resources</td>
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<tr>
<td>Kauffman’s NK(C) Model</td>
<td>Network density and complexity</td>
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...
How the Game works

e.g. “What is the hotkey for . . .?” How to customize the game, change the settings, deal with technical issues, etc.

Pick ONE OR TWO people
You can pick yourself.
◆ **Quests**

e.g. which NPC do you talk to, where do you go, what do you need, etc.?

Pick ONE OR TWO people
You can pick yourself.
- **Blacksmithing, Enchanting, Leatherworking**

  e.g. what is the purpose of an item, how to make or get an item, where to find materials, paths to follow, etc.

  Pick ONE OR TWO people
  You can pick yourself.