Network Science Analysis of Reviews of Persuasive Game Strategies

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Abstract

The increasing integration of gamification strategies in various domains such as health, education, sustainability, etc., has gained a growing interest in understanding the relationships and impact of these strategies on persuasive game design. This study provides an update on a project employing network science analysis to evaluate the significance and utilization of specific gamification strategies. Extracted from seventy-seven systematic review articles, persuasive game strategies are represented as nodes in a network graph. Challenges in data gathering and cleaning were addressed through innovative solutions, ensuring the integrity of the dataset. The study highlights the progress made in data collection, cleaning, and successfully visualizing the relationships among the game strategies through a network graph. The study outlines progress in visualization through a network graph and a detailed explanation of centrality measure computation and community detection algorithms applications. Through this research, valuable insights into gamification strategies and their role in persuasive gaming are offered, contributing to a deeper understanding of game design dynamics. This study aims to contribute valuable insights to the understanding of gamification strategies in game design and their impact on persuasive gaming.

Keywords

Persuasive strategies, Games, Network graph, Network Analysis, Game Analysis, Game Design.

1. Introduction

Gamification has gained significant interest in enhancing motivation and engagement across various domains, including business, education, and health [1]. For academics and game designers looking to maximize these components' potential for successful game creation, a comprehensive grasp of these components is lacking [16]. This study addresses this gap by systematically compiling a diverse dataset of persuasive game strategies and employing network science techniques to analyze their interrelationships. By exploring concepts like centrality and connectedness within the network, the research aims to identify the collective impact of these strategies on game design. Through the investigation of influential strategies and their relative relevance, the study aims to provide valuable insights for game design, bridging the gap between academic research and practical application. By providing a thorough network graph representation, the study seeks to uncover the dynamics of persuasive gamification and offer actionable insights for game developers, ultimately advancing practical implementation in the creation of captivating and memorable games.

The following are the research questions this study intends to achieve:

RQ1: What are the key persuasive game strategies identified in the systematic reviews?
RQ2: Can the network analysis provide insights into the relative importance of different gamification strategies?
RQ3: How can the insights from the network analysis inform the practical application of gamification strategies in real game design?
RQ4: Based on the findings, what recommendations can be made for game designers?

2. Related Work

Persuasive technologies are interactive systems intentionally designed to change a person's attitude or behavior in a predetermined way. They can be developed using various platforms such as games, and mobile or web apps. Persuasive technologies can bring about constructive changes in many domains, including health [2]. In this regard, computers can help us improve ourselves, our communities, and our society, thus functioning in three basic ways: as tools, as media, or as social actors — each affording different pathways to persuasion [3]. Persuasive technology has been used in various research fields outside of the traditional domains of human-computer interaction (HCI) and psychology. According to a study by [4], patients with diabetes who received personalized feedback and reminders from a mobile persuasive game to promote healthy habits to treat chronic disease increased their adherence to medicine. Another study discovered that a persuasive game that inspired asthmatic kids to correctly use their inhalers improved their inhaler technique [5].

Persuasive technologies make use of persuasive strategies to bring about a change in attitude or behavior. Persuasive strategies are just-in-time nudges that when applied at the right time and the right way will lead to a change in behavior or attitude. Several taxonomies of persuasive strategies exist such as Cialdini's six persuasive strategies [14]. They include:

- Reciprocity: Individuals influenced by reciprocity are likely to return the favor.
- Commitment: Individuals influenced by commitment consistently keep their word when they commit to something.
- Social proof: Individuals influenced by social proof look to others in their social circle when unsure of how to behave or what decision to make.
- Authority: Individuals influenced by authority listen to authority figures.
- Liking: Individuals influenced by liking listen to people they like.
- Scarcity: Individuals influenced by scarcity crave things that are limited in edition or scarcely available.

Since persuasive technologies are developed using persuasive strategies, it is important to determine the strategies that are commonly used for persuasive games for healthy nutrition. This information can help educate game developers or others working in the field of persuasive technology on the strategies to use while creating persuasive games.

3. Methodology

This study methodically investigates gamification strategies by compiling a broad dataset from research articles, systematically classifying them, and constructing a network graph representation. Utilizing advanced network science methods, it analyzes the intricate connections among these strategies, going beyond visualization to assess their real-world applications and effects in game creation. Through evaluating centrality and connectivity, the study offers comprehensive insights into how these strategies collectively influence the design and effectiveness of games. With these goals in mind, the study aims to advance the scholarly conversation on gamification while also offering practical insights into the ever-evolving field of game development games.

Some of the persuasive strategies are enumerated as follows:

- Rewards: They assist players in keeping track of their advancement and establishing their status. Rewards can be implemented as points, badges, coins, badges, etc. Rewards are awarded for completing activities within a game.
- Levels: They are used to indicate that a player has reached a particular milestone in a game.
- Feedback: This is a way of regularly notifying the player of their goals, mission, challenges, and achievements within a game.
- Leaderboard: It shows a player's overall performance and ranking in comparison with other players in the game.
- Personalization: This principle emphasizes the need to provide user-centered information to the player.
- Self-monitoring: This principle helps the user to track their progress to achieve a goal.

3.1. Data Collection

This study's data collection process follows a rigorous and systematic approach to gathering pertinent scholarly works on gamification strategies. A literature search was conducted between September 2023 and November 2023 using four (4) databases: IEEE Xplore, Google Scholar, ACM Digital Library, and SpringerLink. The search terms used were Network graph, Network Analysis, Game Analysis, Persuasive strategies, and Games. 150 articles were identified. After reviewing the titles for relevance, 50 of them were excluded. Of the remaining 100 articles, after reviewing their abstracts, 23 were excluded. 77 papers were eventually reviewed for this study as seen in Table 1. This research study was conducted by the authors. These articles encompass a diverse range of topics, including persuasive strategies in games for behavior change, gamification in healthcare, e-learning applications, and the role of serious games in promoting healthy nutrition.

4. Methodology

The persuasive strategies were extracted from articles that did a systematic review of persuasive strategies. The focus was particularly on different persuasive strategies mentioned in each article review because they will give insight into strategies frequently used in designing persuasive games [17], [18], [19], [20]. According to [21] the strategies may be categorized as providing primary tasks, dialogue, system credibility, or social support. For this study, the total number of strategies obtained for each category is seen in Table 1.

Table 1
Categorization of Persuasive Strategies

| No. of articles from the survey	Primary task	Dialogue support	System credibility	Social support
77	15	15	5	9
Total persuasive strategies obtained (nodes) = 44				
Total number of edges = 137				

4.1. Network Graph

A network graph was used to determine what persuasive strategies are influential and could be recommended for the design of persuasive games based on the data collected. In the network graph, nodes are denoted using persuasive strategies and edge (connection between nodes) as the frequency of usage of the strategies in an article. Two nodes (persuasive strategies) are connected if they have been reviewed by the same article. The size of the node represents the degree of the node, which is a measure of how popular that node is; the bigger the node, the more popular the persuasive strategy is and the

more it has been reviewed. The thickness (width) of the edges between two nodes (persuasive strategies) shows how many articles have reviewed both persuasive strategies; a very thick edge between two nodes (persuasive strategies) shows that both strategies have been reviewed by more articles compared to other pairs of persuasive strategies. Figure 1 illustrates the network graph of all the persuasive strategies obtained from the dataset, with categorization shown in various colors based on the Grouping as seen in Figure 2. To determine how influential strategies were identified using this graph, the node size was one factor as well as the community to which they belong.
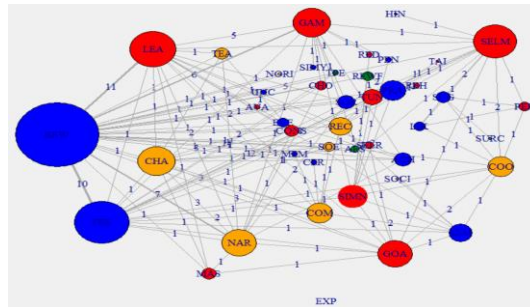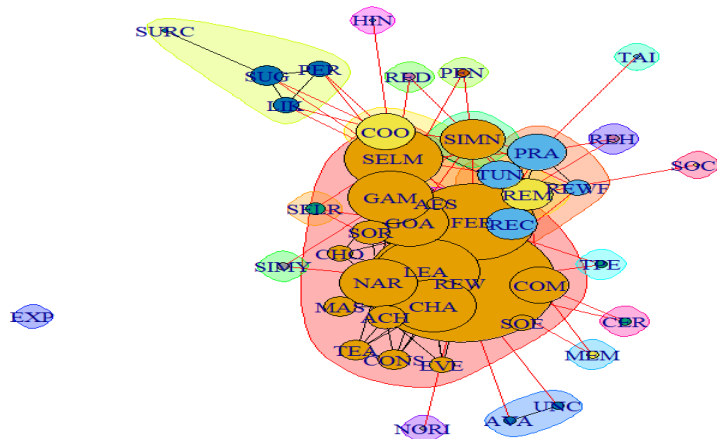

Figure 1: Network Graph of Persuasive Strategies
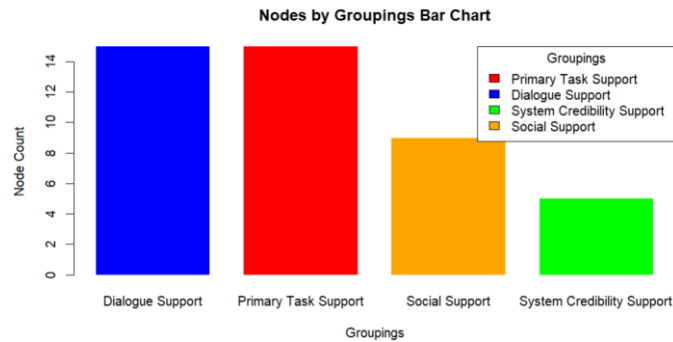
Figure 2: Persuasive Strategies categorization.

4.2. Community Detection

The communities in this network graph were identified using an algorithm called cluster_edge_betweennes as shown in Figure 3.

Figure 3: Network Graph of Persuasive Strategies

The cluster-edge-betweenness method was used in this analysis because it identifies communities in a network by examining the betweenness centrality of edges. Betweenness centrality is a measure of the importance of an edge in connecting different parts of a network. In the context of community detection, edges with high betweenness centrality are considered potential bridges between different communities [22]. The method involves iteratively removing edges with the highest betweenness centrality from the network. The removal of these edges can disconnect the network or split it into separate components. The remaining connected components after edge removal are considered as communities. Using the cluster-edge-betweenness method, twenty (20) communities were detected however, five are shown below.

Community 1 Size: 17 Nodes: Rewards Feedback Leaderboard Goals Self-monitoring Game levels Competition Social role Challenges Narrative Mastery Events Constrains Achievements Teams Social engagement Choice.
Community 2 Size: 4 Nodes: Praise Real world feel Recognition Tunneling
*Community 3 Size: 1 Node: Self-regulation*
Community 4 Size: 2 Nodes: Cooperation Reminders
Community 5 Size: 4 Nodes: Liking Personalization Suggestions Surface credibility.

Community 1, the largest cluster, encompasses diverse persuasive game strategies like Rewards, Feedback, Leaderboard, and Goals. These strategies, frequently highlighted in systematic reviews, suggest their effectiveness in game design. Connections within this community, such as Self-monitoring and Achievements, indicate their contribution to goal attainment. This diversity suggests a comprehensive approach to persuasive game design, forming a foundation for well-balanced strategies integrating various motivational and engagement factors.

4.3. Central Measures

Degree centrality: The degree centrality values indicate the number of connections (edges) associated with each node in the network. The "Rewards" node has a degree centrality of 29, which is notably higher than the mean degree centrality of the entire network (6.23). The high degree of centrality of the "Rewards" node suggests that it is heavily connected to other nodes in the network. In the context of persuasive game design, this could mean that rewards play a central role and are frequently linked or associated with other game strategies such as Feedback and Leaderboard [24]. The high degree of centrality of "Rewards" supports the idea that rewards are a key persuasive game strategy. This aligns with systematic reviews that often identify rewards as a significant factor in influencing user behavior and engagement [25]. The strong connections of "Rewards" with other nodes suggest that rewards may contribute significantly to the effectiveness of persuasive game design by influencing and being influenced by various strategies in the network. The relationships may involve feedback, goals, achievements, and other related strategies. The high degree of centrality indicates that "Re-wards" holds a central position in the network. This suggests that, in the relative importance of gamification strategies, rewards play a pivotal role and are likely to have a broad impact on the overall game design [24]. The mean degree of the network is approximately 6.23 which suggests, on average, each node is connected to about 6 other nodes in the network.
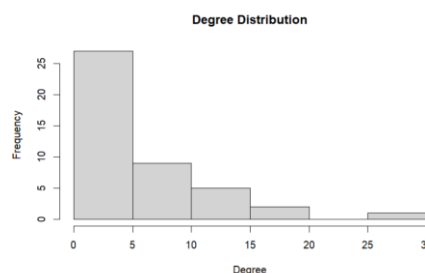
Figure 4: Communities based on Edge-Betweenness.

Figure 4 showcases a wide variation in node degrees, ranging from 0 to 29. Nodes such as "Rewards," "Feedback," and "Self-monitoring" exhibit relatively high degrees, indicating significant connections. With a network density of 0.1448203, identified persuasive game strategies may not be highly interconnected. Certain strategies like "Rewards," "Feedback," and "Leaderboard" stand out independently, crucial in persuasive game design. The degree distribution follows a power-law trend, consistent with the 80% - 20% rule [26]. Only 20.45455% of nodes become hubs, crucial in controlling network connectivity. This suggests that a few key components play pivotal roles in shaping persuasive games [26].

Edge Betweenness: Edge Betweenness measures the centrality of individual edges within a network, indicating the importance of each edge in facilitating communication and influence within the network. It quantifies the number of shortest paths between pairs of nodes in the network that pass through a particular edge. Higher Edge Betweenness values indicate edges that serve as crucial bridges between different parts of the network, potentially controlling the flow of information or influence. Cluster Edge Betweenness, on the other hand, assesses the centrality of edges within clusters or communities of nodes within the network. It focuses on the importance of edges in connecting different clusters rather than individual nodes. Higher Cluster Edge Betweenness values suggest edges that play key roles in connecting distinct clusters, thereby facilitating communication and interaction between different parts of the network.

Table 2 displays Edge Betweenness values, revealing crucial relationships between game strategies. For instance, the link between "Rewards" and "Self-monitoring" has a significant betweenness centrality of 65.5, emphasizing its pivotal role. Similarly, connections like "Feedback" and "Rehearsal", "Leaderboard" and "Reminders" indicate their importance with betweenness values of 29.87 and 17.5 respectively. These strong ties signify key persuasive components that function as network hubs, vital in persuasive game design. Higher edge betweenness values suggest important connections, influencing communication and overall persuasive dynamics within the game [27].

Table 2
Edge Betweenness of Graph

S/N	Strategy 1	Strategy 2	Weight	Edge Betweenness
1	Rewards	Game levels	6	30.84359
2	Feedback	Self-monitoring	5	65.500007
3	Leaderboard	Feedback	10	16.794391
4	Self-monitoring	Leaderboard	11	10.905556
5	Goals	Goals	3	15.47774
6	Game levels	Tunneling	2	18..54359
7	Praise	Self-regulation	1	22.9
8	Recognition	Normative influence	1	42
9	Tunneling	Social role	1	14
10	Narrative	Recognition	1	15.022222

Closeness Centrality: Closeness centrality is a network metric that measures how central a node is to the overall network by calculating the average distance from that node to all other nodes [28]. Higher closeness centrality values indicate nodes that are, on average, closer to all other nodes in the network.

Table 3
Top-ten Closeness Centralities

S/N	Node	Closeness
1	Rewards	0.01754386
2	Feedback	0.01515152
3	Leaderboard	0.01428571
4	Self-monitoring	0.01428571
5	Goals	0.01351351
6	Game levels	0.01351351
7	Praise	0.01298701
8	Recognition	0.01265823
9	Tunneling	0.01265823
10	Narrative	0.01250000

Nodes with high closeness centrality values, such as those greater than 0.012 as seen in Table 3, are central to the network in terms of average proximity to other nodes. Closeness centrality values of nodes related to different gamification strategies have identified which strategies are central to the overall network structure. Nodes with high closeness centrality represent strategies with broad influence and how often they are used in reviewed articles and game designs.

Eigenvalue Centrality: Eigenvalue centrality is a measure of centrality in a network based on the principal eigenvector of the adjacency matrix. Nodes with higher eigenvalue centrality are considered more central in the network. Nodes with higher eigenvalue centrality, such as "Rewards," "Feedback," and "Leaderboard," are considered more central in the network as seen in Table 4. These nodes are influential and strongly impact the overall network structure. Furthermore, Eigenvalue centrality is often interpreted as a measure of importance or influence. Nodes with high eigenvalue centrality contribute significantly to the overall connectivity and structure of the network [30].

Table 4
Top-ten Eigenvalue Centrality.

S/N	Node	Eigenvalue
1	Rewards	1.0000000
2	Feedback	0.8458687
3	Leaderboard	0.7861014
4	Goals	0.6393071
5	Narrative Goals	0.6248348
6	Self-monitoring	0.6127867
7	Challenges	0.6113098
8	Game levels	0.6011336
9	Recognition	0.4581327
10	Competition	0.4405037

4.4. Largest Clique

The largest clique stands out as a unified and deeply interconnected subset, made up of six strategies: "Rewards," "Leaderboard," "Challenges," "Narrative," "Constraints," and "Teams". This suggests that these components regularly appear together and have linkages in the literature, which may point to their significance as a group in persuasive game design. Further investigation of cliques with a size of six (6) shows that there are several occurrences of separate but related groupings of constituents. One clique, for instance, has the features "Feedback," "Game levels," and "Social role," suggesting a connection between these strategies in the study. Another clique involves "Praise," "Self-monitoring," and "Recognition," indicating potential associations in the context of persuasive games. The identified cliques provide evidence of groups of gamification strategies frequently discussed together, offering

insights into potential key persuasive game strategies. Also, the presence of large and interconnected cliques suggests that certain combinations of strategies contribute collectively to the effectiveness of persuasive game design [33].

4.5. Largest Influential Strategies and Their Contributions to Persuasive Game Design

From the metric analysis carried out in this study, we have been able to identify key strategies or nodes that are described as crucial to the overall network structure. Examples of these strategies are those found in the cliques of size six enumerated above under the Clique section. They include Rewards, Feedback, Leaderboard, Self-monitoring, Game levels, and Social role. According to [34], the study presented a systematic survey on the use and impact of gamification in published theoretical reviews and research papers involving interactive systems and human participants. The results and findings reported in the study that gamification strategies such as Challenges, levels, rewards, time pressure, points, and mini-games led to a positive impact in terms of improved engagement, enjoyment, and learning. In addition, it was discovered that Points, challenges, avatars, and progression impacted positively in areas of improved compliance, reduced blood sugar, and improved quality of life. Another positive impact recorded was that Points, status, badges, and leaderboards brought about improved response speed and quality in the life of the participants [34].

Some of the insights from this study are listed below:
- Rewards, Feedback, Leaderboard, Self-monitoring, Game levels, and social role emerged as crucial strategies in the persuasive game design network.
- The study identified pivotal hubs in the persuasive gaming landscape, including Rewards, Feedback, and Goals.
- Network analysis revealed a moderately sparse structure with 20 discrete clusters, each representing nodes sharing common characteristics.
- Prominent strategies like Rewards, Feedback, and Goals were identified as influential hubs, while closeness centrality scores illustrated potential collaborative influence among select strategies.
- The study offers evidence-based strategies for game designers to enhance connectivity, leverage influential strategies, and explore thematic clusters for targeted persuasive interventions.

4.6. Answers to research questions

RQ1: Key Persuasive Game Strategies:
The systematic review of persuasive strategies identified four main categories: primary task support, dialogue support, system credibility, and social support. Within these categories, a total of 44 persuasive strategies were identified from the reviewed articles. The most used persuasive strategies in game design were found to be dialogue support and primary task support.

RQ2: Insights from Network Analysis:
The network analysis provided insights into the relative importance of different gamification strategies. Nodes with high closeness centrality, such as rewards, feedback, and leaderboard, were identified as central to the overall network structure, indicating their broad influence on game design. Eigenvalue centrality analysis further emphasized the importance of rewards, feedback, and leaderboards as central nodes with strong influence on the network structure.

RQ3: Practical Application of Insights:
The identified persuasive game strategies and their relationships offer valuable insights for practical application in game design. By understanding the centrality and connectivity of these strategies, game designers can strategically enhance connectivity and leverage influential components to augment

overall effectiveness. The largest clique in the network, consisting of rewards, leaderboards, challenges, narratives, constraints, and teams, suggests their collective significance in persuasive game design.

RQ4: Recommendations for Game Designers:
Based on the findings, recommendations for game designers include prioritizing rewards, feedback, and leaderboards as central strategies in persuasive game design. Additionally, leveraging the identified persuasive strategies, such as dialogue support and primary task support, can enhance player engagement and behavior change in game design. Further exploration of cliques and their associations provides insights into potential key persuasive game strategies and their collective impact on game design effectiveness. In conclusion, the survey recorded their findings concerning the effectiveness of gamification were mostly positive (61%), but there was a fair amount (39%) of mixed results. Eight out of 11 (73%) comparative studies showed positive results also [34]. This is a clear indication that the influential strategies discovered in this study from the metric analysis carried out will contribute positively to the design of persuasive games.

5. Discussion and Limitation

This study delves into persuasive game design dynamics, utilizing systematic reviews and network analysis to unveil interconnected strategies, highlighting pivotal hubs shaping persuasive game design. It emphasizes strategic relationships over the quantity of connections, guiding designers to leverage influential components for enhanced effectiveness. A strategic shift towards Persuasive Game Strategies was undertaken, aligning closely with persuasive gaming goals and impacting data collection and theoretical framework. Despite challenges, this adaptability underscores the study's dynamic nature, offering valuable insights shaping the future of persuasive gaming experiences academically and practically. This work contributes significantly by delving into the structural dynamics of persuasive game strategies through network analysis, revealing patterns that shape persuasive gamification. It enables researchers and practitioners to discern key strategies, evaluate their centrality, and understand their collective influence on game design, fostering a deeper comprehension of persuasive gaming. Limitations of this study are that the generalizability of findings may be limited to the specific set of articles included in the analysis, raising questions about the broader applicability of the results.

6. Conclusion and Future Directions

This study underwent significant transformations, shifting its focus from analyzing the complex network dynamics of game mechanics to a detailed examination of Persuasive Game Strategies within game design. This strategic realignment was driven by the recognition of natural connections with the field of persuasive gaming. Key strategies such as Rewards, Feedback, and Goals emerged as pivotal hubs in the persuasive gaming landscape, highlighting their central roles in influencing player behavior. Despite challenges, including the need to re-examine and realign data aggregation methods and analytical approaches, the study systematically reviewed and categorized diverse Persuasive Game Strategies. This process revealed distinct communities within the network, showcasing the intricate relationships defining persuasive strategies. Network analysis unveiled a moderately sparse structure with 20 discrete clusters, each representing nodes sharing common characteristics. Prominent Strategies like Rewards, Feedback, and Goals were identified as influential hubs, while closeness centrality scores illustrated potential collaborative influence among select strategies. Finally, the study's evaluation provides valuable insights for game designers, offering evidence-based strategies to enhance connectivity, leverage influential strategies, and explore thematic clusters for targeted persuasive interventions. It not only emphasizes the current landscape but also lays the foundation for future research into the complex relationships shaping the persuasive gaming experience. For future research, there is a need to track the evolution of persuasive game strategies over time and capture emerging trends in design practices. Additionally, incorporating user feedback and empirical data into the network analysis can enhance the validity and robustness of findings, providing a better understanding of player preferences and behaviors.

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