Exploring Asymmetry of Information in Cooperative Games

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Abstract. Digital gaming has the potential to foster togetherness through shared, challenging, and immersive activities. In cooperative games, asymmetry of information impacts social interactions, yet its effects on player experience are not yet fully understood. To this end, we propose a framework for studying asymmetry of information in game design, expanded from previous work on asymmetry, and apply it to the design and development of a cooperative game prototype. In a study with ten pairs of players, we examined how asymmetry of information affected the player experience, through outcomes such as connectedness, communication, fun, and challenge, through a mixed-methods approach. Findings showed that players perceived differences in the distribution of information, influencing their interactions during gameplay. Future research could focus on enhancing the framework to capture the granularity of information dynamics and investigating the asymmetry of information in different scenarios other than two-player cooperative games, offering deeper insights into gaming dynamics.

Keywords: gaming · asymmetry · cooperative · information · framework

1 Introduction

Games designed to promote social interaction have demonstrated positive effects on players, including improvements to social skills, facilitation of relationship formation and maintenance, and contributions to psychological well-being [7, 20, 8]. Multiplayer gameplay, regardless of the medium - whether played co-located (e.g., split-screen game modes), in the real-world (e.g., location-based games), or online - can foster distinct social experiences. Moreover, multiplayer games, even those not explicitly designed to foster social interaction, naturally involve some level of social interplay by virtue of their design - whether it is team-based competition, cooperative story-driven gameplay, or one versus one adversarial matches -, these different types elicit socialisation both in cooperative and competitive settings. In the context of cooperative games, players are often encouraged to collaborate and communicate to achieve shared goals, which can have benefits [13, 17] such as the development of prosocial behaviour [12, 24, 6], trust [9], and the reinforcement of interpersonal bonds [25, 8]. Moreover, studies indicate that player interdependence, meaning the phenomenon where players are dependent on each other in some way, influences communication dynamics during gameplay, promoting social interaction and enhancing the overall social experience [10, 8].

To fully harness these social benefits, it is important to understand the underlying game dynamics that potentiate them. Previous research has focused on formalising frameworks and conceptual models to capture these game dynamics: game design fundamentals [19, 29, 11], game design frameworks [18, 28], and player motivations and typologies [3, 31, 21]. These studies emphasise the importance of understanding not only individual player behaviour, but also the dynamics that emerge from player interaction within structured game environments. One of these dynamics includes cooperation. Past work [26, 30] shows there are many design patterns that can elicit cooperation, such as synergies, resource sharing, etc. Among these patterns is the use of asymmetry, for which Harris et al. [16] introduced a framework, identifying six types of asymmetry: ability, challenge, interface, information, investment, and goal/responsibility. This notion has since been refined further in other related work: introducing the concept of degrees of interdependence [15]; further extending the framework through analysis of related work on asymmetric gameplay in multiplayer virtual reality games, incorporating dimensions of patterns of shared control and social asymmetries [27]; and separating asymmetry into two categories: endogenous and exogenous [22, 23]. Specifically, asymmetry of information inherently impacts social interactions in games. However, the impact of information asymmetry on the player experience is not yet fully understood.

In this work, we leverage the framework by Harris et al. [16], focusing specifically on the asymmetry of information, "*where one player knows something other players do not*", since asymmetry of information naturally fosters social interaction. By doing so, we propose a framework to capture asymmetry of information and the different ways it can be implemented in digital games. Next, we developed a digital cooperative game prototype with a variety of asymmetry of information implementations. Finally, in a controlled laboratory study involving ten player pairs, we explore the player's perceptions of asymmetry of information, reflecting on their experience in terms of connectedness, communication, fun, and sense of challenge. We leveraged a mixed-methods approach aiming to answer the following research questions:

- **RQ1:** How do players perceive asymmetry of information in a cooperative game?
- **RQ2:** How do different types of asymmetry of information shape social interaction between players in a cooperative game?

The user study revealed that even if not explicitly aware, players intuitively perceived the existence of asymmetry of information and its subcategories. This asymmetry influenced cooperation and progression, with some challenges being negatively received due to their one-sided nature or the perception that both players had access to the same information. Furthermore, unexpected combinations of framework values led to either confusion or excitement. Some combinations created challenging and positively received puzzles, while others caused frustration. These findings provide insights into using asymmetry of information as a tool in game design to create diverse and engaging experiences.

2 Defining Asymmetry of Information

During the conceptualisation of asymmetry of information, we leveraged Harris et al. [16] as a starting point. The authors define asymmetry of information as the situation "*where one player knows something other players do not*" [16]. Through multiple iterations, taking into account related work [16, 15, 27, 22, 23], game mechanics in commercial games that are built on asymmetry, and our own experience with digital and analogue games, we propose a framework to capture asymmetry of information and the different ways it can be implemented in digital games. Throughout this process, the research team met regularly and iterated over the framework's definitions and categories through a shared document. This led to the identification of two categories characterising information asymmetry, *Implementation* and *Awareness*. In this sense, the notion of "information" can be split into how it is implemented and perceived in terms of what it is for, where it is used, who has access to it, and what does it lead to. In turn, all of these are also "information" since, for example, knowing who has access to information is also "information". Below, we present each category's definition, subcategories and possible values. Table 1 provides an overview of the framework.

Table 1. Framework for asymmetry of information.

<table>
<tr><th colspan="8">ASYMMETRY OF INFORMATION</th></tr>
<tr><th colspan="8">Implementation</th></tr>
<tr><th colspan="4">Possession</th><th colspan="4">Utility</th></tr>
<tr><td>Single</td><td colspan="2">Combined</td><td>Split</td><td>Single</td><td colspan="2">Multiple</td><td>None</td></tr>
<tr><th colspan="8">Awareness</th></tr>
<tr><th colspan="4">Possession</th><th colspan="4">Utility</th></tr>
<tr><td>Single</td><td>Combined</td><td>Split</td><td>None</td><td>Single</td><td>Combined</td><td>Split</td><td>None</td></tr>
<tr><th colspan="4">Location</th><th colspan="4">Consequence</th></tr>
<tr><td>Single</td><td>Combined</td><td>Split</td><td>None</td><td>Single</td><td>Combined</td><td>Split</td><td>None</td></tr>
</table>

Implementation Refers to who has the information and who will have to use it. This category comprises the following subcategories: *Implementation of Possession* (i.e., who has the information or who has access to it) and *Implementation of Utility* (i.e., who uses or needs the information).

Awareness Refers to who knows about different aspects related to the information. This category comprises the following subcategories: *Awareness of Possession* (i.e., who knows who has the information), *Awareness of Utility* (i.e., who knows who needs the information), *Awareness of Location* (i.e., who knows where the information is used), and *Awareness of Consequence* (i.e., who knows the consequence of using the information).

Values For the *Implementation* category, the values for *Implementation of Possession* can be *Single* (i.e., only one player has or has access to the information), *Combined* (i.e., multiple players have or have access to overlapping parts of the information), or *Split* (i.e., multiple players have or have access to non-overlapping parts of the information). For *Implementation of Utility*, the values can be *Single* (i.e., only one player uses or needs the information), *Multiple* (i.e., multiple players use or need the information), or *None* (i.e., no player uses or needs the information). In the *Awareness* category, the values for *Awareness of Possession*, *Awareness of Utility*, *Awareness of Location*, and *Awareness of Consequence* follow a similar pattern: *Single* (i.e., only one player is aware), *Combined* (i.e., multiple players are aware of overlapping parts), *Split* (i.e., multiple players are aware of non-overlapping parts), or *None* (i.e., no player is aware). For example, in a game scenario where players possess pieces of a treasure map, *Split* would mean each player holds a unique piece, while *Combined* would mean some or all pieces were shared by players.

3 Designing for Asymmetry of Information

In order to operationalise the framework proposed and ensure greater control over how the asymmetry of information was implemented and manipulated, we designed and developed a proof-of-concept digital two-person cooperative top-down dungeon exploration experience, *Parallel Realms: Asymmetry United*. This design selection was informed by the game genre's broad appeal for cooperative play and its scalability potential, aiming to provide a gaming experience close to a real-world scenario. In this game, players explore a dungeon composed of four floors, where each floor corresponds to a different information-based asymmetric challenge puzzle. Both players are expected to traverse and explore each of the dungeon's floors, defeating enemies, collecting loot, levelling up through experience gathered, and interacting with the environment. On each floor, players may encounter unidentified information rooms and clues for the solution to the given floor's puzzle. Moreover, the final room of each floor always contains a puzzle challenge that players must overcome by articulating the knowledge they have gathered. An example of the Weapon Challenge progression can be seen in Figure 1. Supplementary material, including a gameplay sample, is available online[1]. A downloadable version of the prototype is also available online[2].

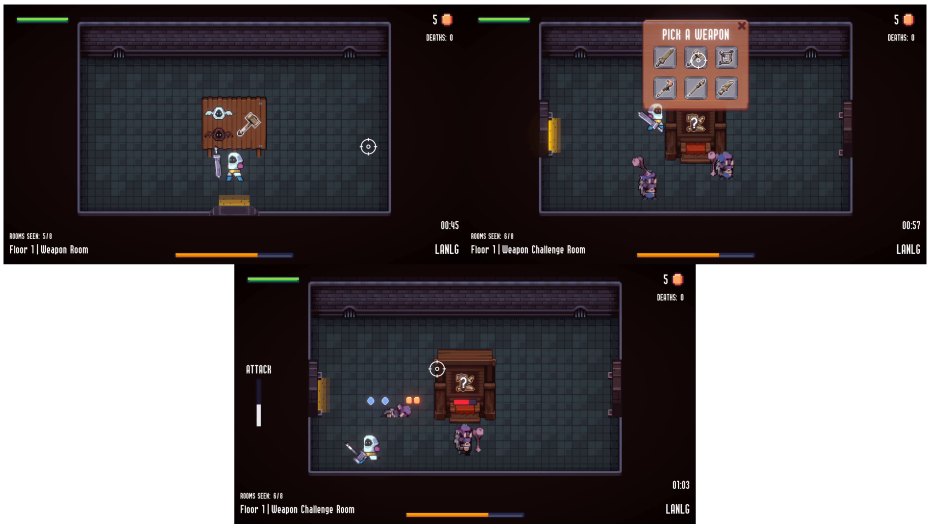

Fig. 1. Gameplay screenshots of the player completing the Weapon Challenge: top-left shows the player interpreting an informational sign, top-right depicts selecting the correct weapon, and the bottom-centre illustrates using it to defeat enemies.

We explore a subset of the possible combinations of values for each of the previously presented subcategories of the framework (Table 2), recognising the infeasibility of implementing and analysing all possible combinations of values in only one study. To ease and expedite the development process, certain subcategory values were chosen. The *Awareness of Location* subcategory was fixed on the *Combined* value since players, a priori to experiencing the game, already knew that the challenges would be found in the final room of each floor. The *Awareness of Consequence* subcategory was fixed on the *None* value, since players did not know what possible abilities they might receive by completing a challenge. If players failed to complete any of the challenges, they would be killed and forced to respawn back at the floor's initial room. This design choice discourages participants from resorting to a trial-and-error strategy in solving the challenges. Finally, the *Awareness of Possession* and *Awareness of Utility* subcategories were paired, meaning that the player who knew who had the information would also know who needed the information.

[1] The supplementary material can be accessed at `https://osf.io/ndwv2/?view_only=f05e5f3942554c779e34d1a160fe0dcb`

[2] A downloadable version of the prototype can be accessed at `https://techpeople.itch.io/parallel-realms-asymmetry-united`

Table 2. Combinations of values from the asymmetry of information framework considered.

Combination	ASYMMETRY OF INFORMATION					
	Implementation		Awareness			
	Possession	Utility	Possession	Utility	Location	Consequence
Skull Challenge	Single (Player A)	Single (Player B)	Single (Player A)	Single (Player A)	Combined	None
Chest Challenge	Single (Player A)	Single (Player B)	Single (Player B)	Single (Player B)	Combined	None
Weapon Challenge	Single (Player A)	Multiple	Single (Player A)	Single (Player A)	Combined	None
Pots Challenge	Single (Player A)	Multiple	Single (Player B)	Single (Player B)	Combined	None
Wolf Challenge	Split	Single (Player B)	Single (Player A)	Single (Player A)	Combined	None
Sequence Challenge	Split	Single (Player B)	Single (Player B)	Single (Player B)	Combined	None

As an example, in the Weapon Challenge (seen in Figure 1) both players individually encounter the same challenge room, which contains an interactable station and two invulnerable enemies. When interacted with, the station prompts the player to choose a weapon out of six different weapons. Picking the right weapon allows the player to defeat the enemies and advance to the next floor; otherwise, the player is killed and respawns back at the floor's initial room. The correct weapon is the same for both players (*Implementation of Utility* is *Multiple*) but only one player has access to the information room revealing it (*Implementation of Possession* is *Single*). The player who encounters the information room understands they have key information needed by both players, as the sign displays both player's symbols and the answer to the puzzle (this player thus has *Awareness of Possession* and *Utility*).

Both type A and B players encounter the Weapon Challenge on the first floor. Type A players face the Skull Challenge, and type B players face the Chest Challenge on the second floor. Both types then encounter the Pots Challenge on the third floor. Type A players face the Wolf Challenge, and type B players face the Sequence Challenge on the fourth floor.

The game was developed for PC using the *Unity Game Engine* [1]. Defeating enemies awards players with experience, allowing them to level up and choose one of three random abilities. Similarly, upon completing a dungeon floor, players are presented with a choice of one of three random special abilities to further strengthen their character.

4 User Study

A controlled laboratory study was conducted with ten player pairs, who responded to questionnaires before and after playing the game. A mixed-methods approach was applied to the data analysis, aiming to answer our previously mentioned research questions.

Participants We recruited 20 participants, aged 19 to 42 years (M = 23.9, SD = 4.79), primarily through university social media, mailing lists, and word-of-mouth. Most participants were university students in Portugal with varying levels of gaming experience, with only one (D2) reporting no prior experience with video games. Participants were encouraged to enrol in the study in pairs, thus attempting to guarantee some level of acquaintance, however, some player pairs had to be matched by the researchers. All but one pair (pair D) knew each other prior to the experiment. We will refer to participants by pair letter and number (e.g. C2).

Procedure The study followed the ethical requirements imposed by our institution. First, participants were informed about the study procedure, and required to fill in a consent form regarding their willingness to participate and share their data, and a demographics form. The latter prompted participants on their name, e-mail, age, self-perceived digital game experience (playing frequency and duration), self-reported investment and competitive profiles, preferred game type and preferred affinity level with play partners. The study took place in a room at our university, with participant pairs seated opposite to each other, each on a laptop. Participant pairs were then given a brief explanation of the game's structure and theme. Participants were informed they could communicate with each other throughout the study and playing sessions were audio, video and screen captured, as well as game events and player actions (e.g., player death) were logged into a database. After experiencing the game, participant pairs were asked to fill out two questionnaires, the miniPXI Questionnaire [14] with a modified scale (5-point Likert scale instead of 7-point Likert scale) and a custom-made experience questionnaire with a 5-point Likert scale. The miniPXI was chosen as it is a validated scale that effectively captures player experience with only a few items. The custom questionnaire prompted participants on their perspectives regarding connection with their play partner, communication quality, fun, challenge, and satisfaction with the play partner's performance, for each of the asymmetric challenges. Moreover, the most liked and disliked asymmetric challenge was also requested. Finally, participants were asked to participate in a semi-structured group interview to understand their perspective on the cooperation throughout the game (i.e., communication needs, missing information, how the game supported and prompted their cooperation), their perspective on the various asymmetric challenges, and game elements they perceived to have influenced their communication.

Data Analysis A descriptive and statistical analysis of the quantitative data provided by the questionnaires was conducted. The results from the demographics form were analysed in order to give an overview of the sample present in the study. We applied a Friedman (predefined significance level ρ=0.05) and Wilcoxon Signed-Rank Test over the metrics of our custom questionnaire (connection, communication, fun, challenge, and satisfaction with the play partner's performance) enabling us to contextualise the data collected. The results from the miniPXI Questionnaire [14] were also analysed to get a sense of the participants' overall experience.

Regarding qualitative data, for this study, only the interviews were transcribed and subject to a mixed deductive and inductive thematic analysis [4, 5]. The coding of the interviews was conducted by one of the researchers involved, and the codebook was initially populated with deductive codes informed by our research questions (e.g., asymmetry, communication) and then expanded with iterative readings of the interviews and notes taken by the researchers during the study. These codes were then discussed amongst all the researchers involved, and revised for redundancy and scope of the research. The coding of the interviews and ensuing discussions about code relationships led to the rationalisation of the overarching themes discussed in the Results section.

5 Results

Ratings resulting from the administration of the modified miniPXI Questionnaire [14] averaged M=4.22 (SD=0.87) for type A participants, M=3.91 (SD=1.05) for type B participants, and M=4.06 (SD=0.97) in total, which indicates an overall positive player experience that is also reflected in participant quotes: "*Genuinely, I liked it a lot. I thought it was a lot of fun.*" (B1). On average, the best-rated components were Audiovisual Appeal (M=4.60, SD=0.50) and Enjoyment (M=4.50, SD=0.51), while the worst-rated one was Mastery (M=3.20, SD=1.11).

There were no statistically significant differences observed in perceived fun ($\chi^2(2)$=2.348, ρ=0.799) or partner performance ($\chi^2(2)$=10.576, ρ=0.060) based on the asymmetric mechanic. However, a statistically significant difference was found in perceived communication ($\chi^2(2)$=12.204, ρ=0.032), connection ($\chi^2(2)$=17.893, ρ=0.003), and challenge ($\chi^2(2)$=17.893, ρ=0.003), depending on the asymmetric mechanic. Post hoc analysis with Wilcoxon signed-rank tests was conducted on these three measures, incorporating a Bonferroni correction with a significance level set at ρ=0.005. In this case, there were no statistically significant differences in perceived communication regarding the different mechanics. However, there was a statistically significant difference in perceived connection regarding the skull and sequence mechanics (Z=-2.871, ρ=0.004), with the sequence challenge being the highest-rated for connection (M=4.65, SD=0.59) and the skull challenge the lowest (M=3.80, SD=1.06). Conversely, a statistically significant reduction in perceived challenge was noted regarding the weapon and sequence mechanics (Z=-3.256, ρ=0.001), with the sequence challenge rated highest for challenge (M=4.42, SD=0.69) and the weapon challenge lowest (M=3.40, SD=1.23).

Cooperative Prompting and Flow Communication between pairs in the study was encouraged by various triggers within the game. Participants identified specific elements like signs, symbols, or interactable objects as cues prompting communication, noting that anything out of the ordinary prompted them to share information with their partner: "*It was whenever I saw a colour or a symbol, anything out of the ordinary, that I felt I had to tell them.*" (B2). For instance, one participant reported that entering specific areas, such as challenge rooms, prompted them to communicate: "*In the red rooms. [...] When you got to a room and there was nothing to kill, you had to communicate.*" (G1). Participants reflected on the flow of communication, noting strategies such as delaying the transmission of information to remember clues for later discussion: "*I'd get to that room, make the connection: 'OK, I'm going to need this for later'. I'd try to remember and then when I got to the other room I'd tell them.*" (D1). While this approach was effective in some cases, others found it less dynamic and organic: "*It makes it a bit... less dynamic. [...] So we keep quiet and then eventually communicate.*" (B2). Frustration and stress from perceived poor performance also hindered communication flow for some participants: "*When you start performing poorly, you get frustrated and end up focusing on things other than communication.*" (E2), highlighting the complex interplay between gameplay dynamics and social interaction.

Impact of Implementation and Awareness During the interviews, some participants intuitively expressed perceptions of the varying subcategories within the proposed framework for asymmetry of information. While unable to articulate specific changes, participants noted a sense of difference in asymmetric mechanics: "*It's almost the same thing, but it's not.*" (H1). This was evident due to their acknowledgment that certain challenges would influence their interdependence and communication. Some subtly identified the fixed, and therefore predictable, nature of the ***Awareness of Location*** sub-category, recognising that it helped guide their actions: "*I didn't necessarily need the key to know that I had to go to the chest. If there was another puzzle, then I needed an indication of which room I had to go to with that answer.*" (E2), indicating that clear spatial indications can reduce confusion, especially when facing multiple potential tasks. Others perceived the ***Implementation of Possession***, noting that certain puzzle elements were exclusive to one player's side: "*Unless I misunderstood, the key to solving the problem wasn't on both sides, it was only on their side.*" (I1). Participants also alluded to certain values of sub-categories, such as ***Multiple*** in the ***Implementation of Utility*** or the concept of ***Combined*** values: "*For example, we might both have to choose the same thing in some cases.*" (J2); "*Put them together, and they would represent something in the world.*" (I1). Overall, managing the asymmetry of information relied heavily on participants' dependence on their play partner's perspective of the game, often requiring prompts for information exchange to overcome challenges: "*We always had to get information from our partner.*" (F1). However, complexity resulting from **splitting information** or **communication requirements** occasionally led to confusion: "*The information wasn't directly on either side, so I was a bit confused as to what I was seeing related to what [D2] was seeing and what the answer was.*" (D1). Nonetheless, participants reported a learning curve in the game, where, as they became more accustomed to the asymmetry of information, their performance and effectiveness improved: "*If something didn't go well, the next one I have to pay more attention to.*" (H1).

Information Distribution and Enjoyment Participants expressed a desire for increased interdependence with their play partners beyond situations where progress was blocked. One participant noted that the game's structure involved barriers where both players had to contribute to complete challenges: "*I realised that the game was more oriented towards... Barriers? [...] you both have to pass the puzzles to be able to do it.*" (I2). However, this was perceived negatively as it blocked progress, with another participant suggesting the inclusion of optional information that could aid players without being essential for progress: "*I think I could also use a bit more... Something where the other person's information helps but isn't necessary for progress.*" (I2). This desire for greater interdependence extended to exploration aspects of the game, with participants noting challenges that required **information solely possessed by one player** as hindering cooperation: "*Well, the problem is that either they get all the information and give it to me, or I give it to them.*" (B2). While some compared these challenges to similar experiences in games like *We Were Here* [2], where the exchange of information between players is necessary and beneficial: "*In one sense there was information that one person didn't have and that the other didn't have, and they had to complement the information they had.*" (I2), others found **one-way transactions of information** acceptable only if both sides did not require the same information. However, when **both sides needed information and only one possessed it**, participants found this lack of reciprocity less enjoyable: "*If it's just a transaction, that is, I'm giving them information on a one-off basis, that's fine, but if you both need information, and it's only on one side, I think...*" (I1).

Managing Individual and Shared Progress Some participants acknowledged the need to wait for their play partner to catch up while traversing the dungeon, often finding themselves in situations where they had to wait without knowing what to do next: "*I often waited for them to finish and didn't know what to do.*" (B1). This suggests that achieving interdependence is difficult when players move at different speeds, possibly due to varying skill levels. Conversely, participants who were still engaged in dungeon activities while their partner waited reported feeling a sense of obligation to **provide the necessary information promptly**, leading to frustration when unable to do so immediately: "*The thing is, I had to kill all the beasties to be able to give you the information.*

It was frustrating me." (E1). Participants also reported doubting their previous explorations when struggling with a challenge, sometimes backtracking to check previously seen rooms: "*Because I was always like, I'm missing something, I was going back and forth, back and forth.*" (B1). For instance, on the second floor, type B players averaged 5.20 backtracks (SD=2.90), compared to type A players who averaged 3.50 (SD=2.17). This suggests that **splitting information**, especially when introducing high requirements of **awareness** (e.g., covert information), reduces the **discoverability factor of certain information**. On the other hand, relevant information was located at most in two rooms, sometimes leading players to lose interest in exploring the dungeon floor when they realised this and found the information: "*If I'd already found the altar room and the other room with information, I'd completely lose the motivation to explore the other rooms that I know still exist.*" (F1). **Splitting and dividing information** when players **know they have all the necessary information** to overcome an obstacle could make the rest of the experience irrelevant.

Factors Influencing Difficulty in Conveying Information The perceived impact of genre familiarity on expertise and performance was highlighted, with more experienced players being better able to pinpoint relevant cooperation prompts. Another significant contributor to the complexity was the **splitting of information**, requiring players to articulate their knowledge with their partner to progress, leading to confusion and insecurity about **conveying relevant information effectively**. This was reflected in the concern of some players about missing important details: "*I was always thinking... I was missing something and that I wasn't telling them what I was supposed to.*" (B1). Participants often struggled to understand how the information they shared would impact their partner's side: "*My biggest difficulty was describing things, and I couldn't understand how it would have an impact on the other side.*" (G2). For example, on the second floor, failed attempts at challenges were the most common, particularly for type B players who averaged 3.00 failures (SD=1.49). Challenges involving **communication requirements**, such as describing information accurately or making covert associations, further added to the complexity. One participant noted: "*We should have communicated better. Some parts. There was something missing there. A better explanation of what we saw and so on. And then that makes it very difficult to move on.*" (B2). Participants struggled with conveying the **importance of certain information**, particularly colours or symbols, which hindered effective communication: "*The only problem I had was the difficulty in explaining how important the colours were.*" (I2).

Coherence Expectations Participants had expectations for coherence in the game's challenge configuration, anticipating consistent mechanics and difficulty progression. However, deviations from these expectations sometimes led to confusion. For example, participants expected information to be scattered throughout the dungeon: "*When I joined the game, I expected that each room would have a little piece of information hidden in a corner.*" (F2), and when these expectations were not met, confusion ensued. Additionally, participants anticipated consistency in the mechanics of the game after encountering their first asymmetric challenge: "*The one with the weapon because it was the first one, and I realised more or less what the game was about.*" (C1), which occasionally caused confusion when the game deviated from these expectations. Despite this, participants appreciated the coherence in the game's difficulty progression, finding that challenges became progressively more difficult: "*Each of these challenges gets harder. So the first two weren't much of a struggle and the other two were more difficult.*" (D2). For example, on the first floor, both player types had a 100% success rate in completing the floor's challenge, while on the last floor type A players had 90% and type B players, 60%. They enjoyed drawing on past experiences to overcome obstacles and found satisfaction in applying learned concepts to more complex scenarios, such as utilising knowledge gained from earlier challenges to solve later ones: "*I also liked the fact that you start with something simple and then use it later with a more complicated puzzle.*" (E2).

Player Dynamics and Communication Participants highlighted the relevance of familiarity and trust between play partners in shaping communication dynamics. For instance, in situations where participants did not know each other beforehand, the level of connection influenced their ability to decipher each other's intentions and convey information effectively: "*We didn't already know each other, so I think it's different from being with someone you already know and who, as [D1] said, you already know, you already know how they react... It's different.*" (D2). Trust, both in oneself and in the play partner, emerged as a significant factor affecting communication: "*Then I was afraid whether the communication I was giving was the right one or not. So it affected my communication and it also affected [A1]'s.*" (A2). Some participants expressed worry about conveying accurate information, while others felt confident in their attempts to assist their partners: "*I was at least trying to help them with what they needed to do.*" (B1). However, there were instances of hesitancy, particularly after negative outcomes following communicated actions, which affected participants' willingness to trust their partners' instructions: "*When you then said yellow [...] I click on yellow, then I die. Then I'm afraid, based on that communication, to do anything else.*" (A2).

6 Discussion

In this discussion, we review the feedback from participants, delving into our findings regarding their views on the asymmetry of information in the game. We also explore how this asymmetry affects social interactions among participants, connecting our observations to the proposed framework.

Perceptions of Asymmetry of Information Participants intuitively recognised aspects of asymmetry of information, especially those familiar with similar games (e.g., *We Were Here* [2]). Even without explicit identification, the challenges impacted their cooperation and progression. For example, the mixed reception of **one-sided information** and the need for **shared information** indicate an inherent understanding of subcategories such as ***Implementation of Possession*** and ***Implementation of Utility***. Each challenge's unique combination of subcategory values sometimes disrupted these expectations, leading to varied responses, ranging from confusion to positive engagement. For instance, puzzles where one player unknowingly held crucial information and the other knew that, were often well-received, which is supported by the quantitative results in which, on average, the Sequence Challenge was considered the most challenging (M=4.42, SD=0.69) but also the highest-rated for connection (M=4.65, SD=0.59). These observations highlight the framework's potential as a design tool. By intentionally disrupting expectations and strategically combining subcategory values, designers can enhance curiosity, experimentation, and replayability.

Impact of Asymmetry of Information on Social Interactions The asymmetry of information served as a catalyst for social interaction in the cooperative experience provided. The interdependence required for overcoming obstacles naturally fostered communication and cooperation. For example, participants identified game elements such as signs, symbols, or special rooms as prompts for cooperation. Moreover, strategies such as **delaying information exchange** or prioritising exploration emerged as players navigated the game, either to strategise or due to reluctance to engage with their partner when not necessary. While individual characteristics, player connection, trust, and performance influenced these social dynamics, asymmetry of information played a key role in shaping communication flow. However, different configurations of asymmetry of information elicited varied responses. For instance, challenges with **one-sided information exchange** or **minimal input from both participants** were often viewed negatively, resulting in reduced interaction. This is supported by the quantitative results, where the Skull Challenge, an example of such cases, was the lowest-rated for perceived connection on average (M=3.80, SD=1.06). In contrast, **covert information** (e.g., clothing items' colours) prompted more significant cooperation due to its complexity, which was for example the case for the Sequence Challenge. On the other hand, the ability to complete a challenge and the quality of interactions, influenced by complexity, affected perceived communication quality, reflected in ratings of challenge of these mechanics. Overall, despite the innate complexity of the designed mechanics, the complexity added by different types of asymmetry of information and by the need of players to learn and improve communication skills with their play partner has an impact on the number of interactions between players as well as the quality or depth of these interactions.

Limitations and Future Work The study presents an initial framework for understanding the implementation of asymmetry of information in games. The findings and implications are based on specific values within the framework and may not apply to all game types and contexts, acknowledging the infeasibility of covering all possible design permutations and contexts. The user study was conducted with 20 participants with specific game profiles which were not controlled, and with a specific game genre and mechanics which may not generalise to other game contexts and populations. Furthermore, the order in which participants engaged with the different implementations of asymmetry of information was static, which could have influenced perceptions of difficulty and social interaction. However, the research highlights the significant impact of asymmetry of information on social interactions in a two-player cooperative game setting. Future studies could explore additional combinations of values and their effects on players' perspectives and interactions. There is potential for further exploration of asymmetry of information in different types of gameplay and across various game genres. Understanding how this type of asymmetry is influenced by player dynamics (e.g., trust) and characteristics, and exploring their effects in family play and intergenerational gaming may offer valuable insights into gaming dynamics. The study recognises the limitations of its controlled laboratory approach and suggests incorporating more realistic scenarios in future research, such as conducting long-term observations in natural settings.

7 Conclusion

Addressing a gap in understanding nuanced variations of asymmetry of information, our study proposes a framework to analyse, ideate, design, and discuss asymmetry of information in gaming. We developed a digital cooperative game, exploring some of its dimensions, where players engage with information-based challenge puzzles. Through a user study involving ten pairs of players, we examined how various types of asymmetry of information influenced social interaction and player perspectives. Participants perceived asymmetry, influencing cooperation and progression. Asymmetry drove social interaction, shaping communication patterns and player engagement. Different configurations of asymmetry elicited distinct reactions, highlighting its impact on communication effectiveness and gameplay dynamics. Our study underscores the importance of understanding and leveraging dynamics such as these for crafting engaging and socially enriching gaming experiences. Future work could further explore how to capture the granularity of information dynamics and exploring asymmetry of information in various contexts beyond two-player cooperative games.

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