Economic game theory and video games

- Using game theory to analyze a strategic video game

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by

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- Using game theory to analyze a strategic video game

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Abstract

This thesis examines how economic game theory is usable in the analysis of a strategic video game (Company of Heroes). The work is centred on two main subjects, one that relates to the actual usage of game theory and one that relates to the results of this process.

The research question is: **How can game theory be used to analyze a strategic video game in relation to gameplay? - And what information does such an analysis provide?**

The general idea is to analyze a game theoretic game that represents the strategic video game. The main problem lies in constructing this game.

My first approach was to construct the game theoretic game purely based on the video game itself. This resulted in far too complex game theoretic games that were impossible to analyze, so I had to take another approach.

This second approach involved player representatives who acted as a sort of interpretation layer between the video game and the game theoretic game. This approach made it possible to construct a game theoretic game that represents the strategic video game. Some important representational problems were however also identified that can not be ignored.

Analyzing the resulting game theoretic game yielded various results. Most significantly did the work with analyzing Company of Heroes reveal information in relation to:

- The strategies of the game
- The balance of the game
- The usage of signals in the game

The analysis revealed the most worthwhile strategies and how these were balanced. In addition to that a connection was found between top players, game balance and game theory.

Furthermore the use of game theory allowed for an in-depth analysis of the signalling opportunities in the game. I learned that only two out of eleven possible signals were actually being used and in combination with a game theoretical analysis the reasons for this were identified as:

- Lack of game mechanical possibilities
- Lack of strategic interdependence

This highlights the strengths of using game theory as an analytical tool in connection to strategic video games. It technically connects the game mechanics to decisions of high abstraction, which consequently makes game theory interesting in relation to analyzing the gameplay of the video game.

Preface

In relation to my work with this thesis I would especially like to thank George Channing aka 12azor for his great contributions.

I would also like to thank the four other Company of Heroes representatives: Wyatt Kopka, Steven Uray, Evans Boney and Jason Heck.

Finally I would also like to thank my supervisor Ole Ertløv Hansen for great input throughout my work with this paper.

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1. Introduction

> “Any game designer should agree that gameplay is the core of the game” (Rollings & Adams, 2003)

When designing a video game the goal is most likely to end up with a game that people want to play. A game designer’s main responsibility in this process is designing the environment and the rules. The overall experience a player gets from playing a game based on those (the rules and the environment) is termed gameplay. Gameplay is therefore not the result of experiences based on graphics, story or sound (Rouse, 2005).

So from the designer’s perspective gameplay is all about rules and environment. But from the player’s perspective, what is gameplay?

Sid Meier once defined gameplay as being “a series of interesting choices”. This clearly defines that *choices* is what gameplay is about from the player’s perspective. Furthermore these choices have to be *interesting*.

This means that the game designer through the design of the rule set and the environment has to create some kind of framework that supports this interesting decision-making process. This can be done based on gut feeling, experience and intuition but this thesis will focus on a more theoretical approach, namely *game theory*.

Rollings and Morris connect game theory and gameplay in the following way:

> ”Strictly speaking, game theory is a branch of economics in which systems governed by rules are mathematically analyzed to determine the payoffs of various end points. The strategies required to reach specific endpoints are collectively called gameplay” (Rollings & Morris, 2004)

Game theory is then actually not a theory, but rather a technique that allows us to mathematically analyze systems governed by rules. Rollings and Morris describe the strategies required to obtain these payoffs as gameplay.

A system governed by rules is then the framework or foundation of the *decision-making process* and game theory is the technique that allows us to understand the *system* and the *rules.*

1.1. Approach

But how is such a game theoretic analysis performed? My approach includes the following two key elements:

i. Construct a game theoretic game (by mapping video game choices)

ii. Perform a game theoretic analysis on the constructed game

The construction of a decision tree is a common way of mapping a situation onto a game theoretic game (i). In connection to this Salen and Zimmerman write:

> “Creating a decision tree can be a powerful way of understanding the formal structure of a game. It is in essence a way of mapping out a game's formal space of possibility. For a simple game such as Tic-Tac-Toe, the complete space of

> possibility can in fact be diagrammed. However, not all games can be mapped out in this way." (Salen, 2004)

Salen and Zimmerman then conclude that only a very specific type of games are mapable (and consequently analyzable) using game theory. These are the games that have the following qualities (Salen, 2004):

- Time in the game takes place in turns or other discrete units.
- Players make a finite number of clear decisions that have knowable outcomes.
- The game is finite (it can't go on forever).

To require the three qualities in order to perform a perfect mapping of a game seems fair. This does however exclude most strategic video games which made me wonder whether another approach to the mapping process would make a game theoretic analysis possible. Possibly through the addition of an interpretation layer that could serve as some kind of complexity reduction mechanism – or maybe by simply mapping a small part of the video game that has all three qualities?

When this game theoretic game has been created the actual game theoretic analysis can begin (ii). By performing such an analysis the best strategies for each player will be identified presuming both players are 100% rational. Besides the obvious purpose of identifying dominant or dominated strategies the results might add to our understanding of gameplay in relation to the strategic choices in a video game. These results however rely heavily on the success of the mapping process (i).

1.1.1. Focus and assumptions

In this section I will shortly describe the focus and general assumptions of this thesis.

Based primarily on the general characteristics of game theory I have chosen to focus my work by selecting a game that is both strategic[1] and two-player. The game chosen is Company of Heroes v. 1.7[2] (more on this choice in section 3.2.2.3) which also is playable solo or with more than one opponent. I will however not cover those situations.

A general assumption of this thesis is that players are rational as it makes no sense to analyze something mathematically if players are allowed to be irrational. I will not discuss this subject extensively but just assume that players are rational, essentially meaning that they want to win. Another assumption is that the players have perfect knowledge about the game as it eliminates the obvious source of error that relates to differences in skill level of the players.

1.1.2. Related work

Many people have reflected upon the similarities between economic game theory and video games[3], but few have actually attempted to use the two in combination.

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[1] Pedersen describe strategy games as "… that require "thought" and "planning." The game's winner is determined through a "battle of the minds." (Pedersen, 2003)

[2] 1.7 is a well known stable version prior to the expansion Opposing Fronts

[3] (Salen, 2004), (Rollings, 2004)

Emmanuel Guardiola and Stephane Natkin belong to the latter group as they have tried applying game theory to a single-player game (Ninja Gaiden). They examine low level choices through the eyes of game theory (Guardiola, 2005). This is possible because it is a relatively simple game and it involves only one human player. So although their approach is similar to mine the fact that I am looking at a video game with two human players makes it quite different.

Jonas Heide Smith also makes use of game theory in his dissertation, as he adapts techniques from game theory in order to analyze various video games (Smith, 2006). His approach is however on a higher level of abstraction than mine. The reason for this is probably that a game theoretic analysis is just a part of his dissertation and not really the core subject.

1.2. Research question

Based on the previous sections I have chosen my research question:

- **How can game theory be used to analyze a strategic video game in relation to gameplay? - And what information does such an analysis provide?**

Based on this research question I aim to reveal how game theory is applicable to a strategic video game in relation to gameplay, which effectively means that I will not focus on the structure of story, graphics etc. but focus on the decision making process based on the game mechanics. Based on the results of this process I will then examine what kinds of information this approach has revealed.

In the process of answering the research question I will use Company of Heroes as my research subject (3.2.2.3). The aim is however to reveal information that might offer implications of interesting gameplay, not only in relation to Company of Heroes but on a general level.

1.3. Structure

The structure of this paper is as follows. First game theory is introduced (chapter 2). Then gameplay is described and the connection with game theory made clear (chapter 3) before actually applying game theory to various video game situations (chapter 4). Based on the knowledge gained from this hands-on experience the focus is changed to strategies and information (chapter 5). The last two chapters hold a discussion of my work and the final conclusion of the thesis (chapter 6 & 7).

2. Game Theory

As mentioned in the previous chapter game theory is the foundation of this thesis. This chapter will serve as an introduction to the subject.

2.1. The origin of game theory

Game theory as a field of scientific research was born in 1944 with the publication *Theory of games and economic behaviour* by John von Neumann and Oskar Morgenstern (Neumann, 1944). John Nash contributed greatly to the field during the 1950s. The solution concept known as 'nash equilibrium' is one of his most famous proposals. In the 1970s game theory was applied to other fields such as biology and political and social sciences. (Carmichael, 2005).

2.2. What is game theory about?

Before going into detail about game theory, let us have a look at what game theory really is about. Hutton defines game theory as:

> "…an intellectual framework for examining what various parties to a decision should do given their possession of inadequate information and different objectives" (Hutton, 1996)

As Carmichael points out, this is not really a definition of game theory, rather a definition of what it can be used for. This thesis is not about defining game theory on a philosophical level but instead about using game theory principles on a more technical level in order to gain some kind of understanding of video games. So looking into the use of game theory might actually be more interesting.

Carmichael writes:

> "Game theory is a technique used to analyse situations where for two or more individuals (or institutions) the outcome of an action by one of them depends not only on the particular action taken by that individual but also on the actions taken by the other (or others). In these circumstances the plans or strategies of the individuals concerned will be dependent on expectations about what the others are doing." (Carmichael, 2005)

So we are dealing with games of multiple participants (multiplayer games) in which the choices of the participants influences each other (strategic games). (Not surprisingly this corresponds well with the focus of this thesis, as I selected the video game subject based on the primary strengths of game theory.)

Hutton speaks of inadequate information while Carmichael describes that in these games the strategies of the participants will rely on expectations of what the other participants are doing. So the access to information or degree of hidden information is a key aspect of game theory.

Game theory is then basically an analytical tool for examining situations and choices (strategic game) in some kind of framework, where the access to information may be limited for the individuals involved.

2.3. Strategic games and game theoretic basics

Game theory can be used to describe a specific group of games. The games that are analyzable by game theory are well defined mathematical objects (Wikipedia, Game theory). In this section I will try to describe what strategic games are (the term used for the games that are analyzable by game theory that involves 2 or more players). Notice that this section is describing game theoretic games and not table games, video games or anything else.[1]

2.3.1. Number of players

Game theory is usually used to analyze n-player games where $n > 1$. The complexity of the games usually rises as *n* increases. As mentioned this thesis will focus on 2-player games.

2.3.2. Payoff and utility

The goal of any participant in a strategic game is to maximize his or her individual payoff. Payoff is usually specified by a number. For instance getting an apple will result in the payoff 5 for one of the players in the game, while getting a banana will result in the payoff 10. This is sometimes simplified further by assigning letters to the payoffs. Based on payoff A (apple) and payoff B (banana) the utility can then be expressed by $B > A$.

2.3.3. Rational players

In game theory players are always expected to be rational, which means that players always will prefer more utility (higher payoff) to less. As earlier mentioned this corresponds with the focus of this thesis.

2.3.4. Repetition

We call games that are played more than once by the same players repeated games, multi-stage or n-stage games. Games played only once by the same players are called one-shot, single-stage or unrepeated games. The reason to distinguish between these two types of games is that the repeated games incorporate some kind of meta-strategy. The knowledge player A has about player B's decisions in the previous n games will influence his decisions in the current game and vice versa. So analyzing repeated games is not just a question of analyzing n unrepeated games.

2.3.5. Simultaneous-move games

Simultaneous-move games are as the name suggests games where players act simultaneously. Technically it does not matter if the moves are carried out exactly at the same time, as long as the moves are hidden from each other.

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[1] From here on I will describe these games as <u>game theoretic games</u> as opposed to <u>video games</u>

2.3.5.1. Normal form

Describing a simultaneous-move game is usually done using a payoff matrix. This way of specifying a game is called the normal form.

Bob

Alice	Rock	Paper	Scissors
Rock	0 , 0	0 , 1	1 , 0
Paper	1 , 0	0 , 0	0 , 1
Scissors	0 , 1	1 , 0	0 , 0

Figure 2.1: Normal form

The matrix above is the classic game of rock, paper, scissors represented in normal form. The players (Alice, Bob), their strategies (Rock, Paper, Scissors) and the payoffs (0 or 1) of all combinations of strategies are shown. The player on the left, in our case Alice, is called the row player. The reason for this is that she selects from the strategies represented by the rows (Rock, Paper, and Scissors). The other player is naturally called the column-player and he chooses from the strategies represented by the rows. If Alice chooses Rock and Bob chooses Paper, then the payoffs of this specific instance of the game will be found in the first row (Alice choose Rock) and in the second column (Bob choose paper). That cell reads [0,1] which should be read as [row-player's payoff, column-player's payoff]. So in this case Alice gets a payoff of 0, while Bob gets a payoff of 1.

2.3.6. Sequential-move games

Sequential-move games are (opposed to the simultaneous-move games) games where one player moves first. This allows the other play to react on the decision made by the first player.

2.3.6.1. Extensive form

The extensive form specifies a sequential-move game. This is done using a tree-structure, compared to the matrix-structure of the normal form. The tree structure represents (Wikipedia, Extensive form game):

- the players of a game
- for every player every opportunity they have to move
- what each player can do at each of their moves
- what each player knows for every move
- the payoffs received by every player for every possible combination of moves.

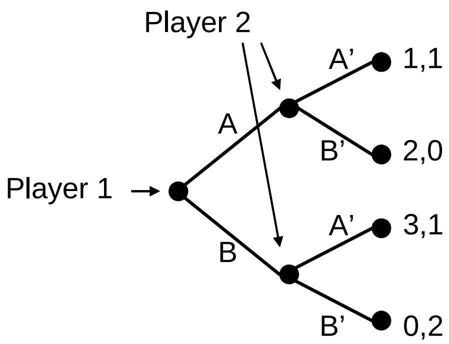


Figure 2.2: Extensive form (Carmichael, 2005)

Compared to the normal form, the extensive form allows the analysis or modelling of games in which the players make several moves. Notice that the above example of a sequential-move game however only includes one choice for each player.

2.4. Equilibria

> "Following the general practice in economics, game theorists refer to the solutions of games as *equilibria."* (Ross, 2006)

This section describes several solution concepts or as above stated equilibria. The reason that the equilibria are important is because they constitute the best choices in any game. Said in other words, if you want to know what your best choice is in a game, then you need to solve it by incorporating the rational choices of your opponent in order to determine what you should do.

In the following I will describe some of the most important equilibriums, which means combinations of both players' best strategies.

2.4.1. Dominant strategy equilibrium

A *dominant strategy equilibrium* describes a game where all players choose their dominant strategy. This means that all players have a strategy that is the best response to any strategy of the other players.

A dominant strategy is shown in this example of the classic prisoner's dilemma:

		Bob	
		Deny	Confess
Alice	Deny	-1, -1	-10, 0
	Confess	0, -10	-5, -5

Figure 2.3: Prisoner's dilemma

In the prisoner's dilemma [confess, confess] clearly constitutes a dominant strategy equilibrium. Seen from Alice's perspective if Bob chooses to deny, then confessing is the best option as it will give a payoff of 0 instead of -1. If Bob chooses to confess, then it would still be the best for Alice to confess, as it will give her a payoff of -5 instead of -10.

This classical game of the prisoner's dilemma constitutes a dominant strategy equilibrium, and for the rational players (which we already defined that everyone is) the best and only choice should be confess.

2.4.2. Iterated-dominance equilibrium

Even though a game does not have a dominant strategy equilibrium, it might have an *iterated-dominance equilibrium*. Let us have a look at a slightly but importantly modified prisoner's dilemma.

Alice		Bob: Deny	Bob: Confess
	Deny	-5, -1	0, 0
	Confess	0, -10	-5, -5

Figure 2.4: Modified prisoner's dilemma

Looking at the matrix for the modified prisoner's dilemma there is no longer a dominant strategy for Alice (since the payoff values for some unknown reason have changed). However confess is still the dominant strategy for Bob. Based on this knowledge we can simplify the matrix to:

Alice		Bob: Confess
	Deny	0, 0
	Confess	-5, -5

Figure 2.5: Modified prisoner's dilemma (iterated)

Based on the knowledge about Bob's decision Alice now has an easy time deciding to deny, as this would give her a payoff of 0 instead of -5. This means that Alice has an iterated-dominance strategy and that this game constitutes an iterated-dominance equilibrium. Notice how this equilibrium is based on the core principle in game theory that the players make their decisions based on the expected decisions made by the other players in the game.

2.4.3. Nash equilibrium

If a game has a *Nash equilibrium* and all players are playing their Nash equilibrium strategy, then no player has the incentive to change strategy. Said in other words the players are choosing responses that are best responses to each other. This does however not mean that these are the best responses to any of the other player's strategies.

Let me illustrate this in the following matrix:

Company B

Company A

	Campaign A	Campaign B	Campaign C
Campaign A	2 , 5	5 , 2	3 , 0
Campaign B	5 , 2	2 , 5	3 , 0
Campaign C	0 , 3	0, 3	7 , 7

Figure 2.6: Nash Equilibrium

The above matrix describes a game in which two companies are planning their next campaign. I have underlined the best choices for each company based on the other company's choice of campaign. If company B chooses campaign A, then the best choice for company A is campaign B as it will result in a payoff of 5 compared to 2 and 0. Notice how the best response to either company launching campaign C is launching the same campaign. This constitutes a Nash equilibrium, since none of the companies will gain anything from switching to campaign A or B making the decision pair best responses to each other.

Every dominant strategy equilibrium and iterated-dominance equilibrium is also a Nash equilibrium (Carmichael, 2005). Let us use the underlining technique on the prisoner's dilemma that we know has a dominant strategy equilibrium:

Bob

Alice

	Deny	Confess
Deny	-1, -1	-10, 0
Confess	0, -10	-5, -5

Figure 2.7: Prisoner's dilemma (best responses are underlined)

Here we see that [confess, confess] constitutes the Nash equilibrium, while it is visually shown that confess for both players is the dominant strategy (in no situation is deny the best response).

2.4.3.1. Mixed strategy equilibrium

Sometimes a game in strategic form does not have a Nash equilibrium like the one mentioned above. In situations where choosing pure strategies (Deny or Confess for instance) does not form a Nash equilibrium the solution concept is called a mixed strategy. A mixed strategy consists of a number of pure strategies along with a probabilistic weighting of these strategies. A mixed strategy equilibrium is formed when both players are playing their mixed strategy. An example of a mixed strategy could be to choose the pure strategy Deny with a 60% probability and to choose Confess with a 40% probability.

It is however important to notice that mixed strategies primarily applies to repeated games.

3. Gameplay

After having looked into the core concepts of game theory in the previous chapter let us now have a look at the connection with the gameplay of strategic video games.

As stated earlier the reason for trying to apply economic game theory principles to video game design is to examine if this could result in the production of games with a more interesting gameplay. To be able to apply game theory in any meaningful way we must first establish a solid understanding of gameplay. When this has been done it is important to take a look at the basic structure and premises for both economic game theory and gameplay in order to establish if there is any justification to the attempt of using game theory in this context.

The goal of this chapter is then to gain a precise understanding of the concept of gameplay and to understand how this relates to the structure and implementation of a strategic video game. Based on that knowledge focus will be on how game theory relates to this.

3.1. A circular model of gameplay

Gameplay is one of the most frequently used words when talking about video games. It is however also one of those words which are hard to define. As already mentioned one of the most famous attempts of defining the phenomena is the one proposed by Sid Meier - that gameplay is “a series of interesting choices” (Rollings, 2004, 61). Other definitions share the idea that gameplay is about the experience of playing the game when making decisions.

Tom Heaton has created a model called “a circular model of gameplay”. It consists of three basic elements: The player, the game and the interaction between them. My understanding of gameplay on a structural level is highly based on this model and in the following I will explain how the model should be read. Notice that the model does not show what good or bad gameplay is. Instead it shows the mechanics, structure and flow of an interaction in which gameplay occurs.

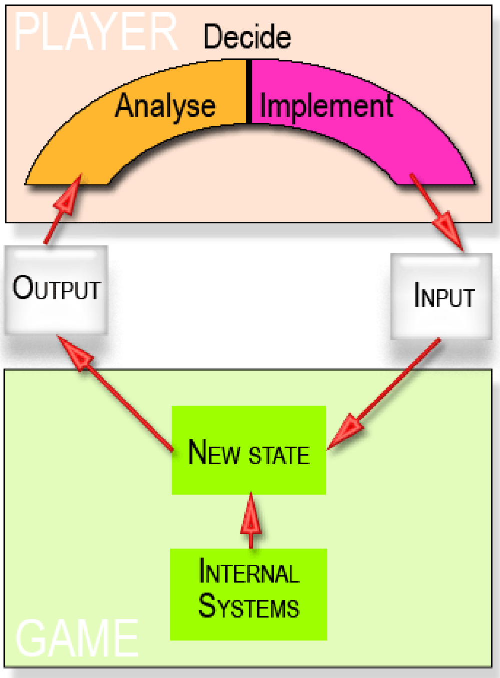


Figure 3.1: Tom Heaton's Circular model of gameplay (Heaton, 2006)

Let us take a look at these three elements one by one.

- The interaction between the player and the game is through input and output signals. Notice how this model of communication is well known from general software development (Mathiassen, 2001).
- The player obviously represents the person interacting with the game. Looking at the player element in the figure we see that his or her role is to make decisions based on an analysis which result in some kind of response (implementation of the decision). Notice how Heaton in this manner base his understanding of game play on this decision making process.
- In the model a state machine represents the game. State machines are an often used construction in computer science and represent a very mechanical yet simple way of understanding a system (Kingston, 1990). The state of the game can be changed by input from the player. Internal game mechanics can however also change the state of the game. The situation where other players change the game state is included in the 'internal systems' square in the model. This is obviously a pretty crude way of presenting the opponent in a multiplayer game and this is where I have decided to modify the model to better suit those games.

The circular flow, indicated by the arrows in the model, is carried out in cycles with the player's decision process in the centre. Heaton emphasizes the importance of this step and regarding strategy games, which this thesis focuses on, he states:

> "As a rule of thumb, strategy games tend to test the player's analytical skills, their reading of the game situation, and their weighing up of the options. Therefore decisions are important in strategy games because they constitute the test of those analytical skills." (Heaton, 2006)

According to Heaton decisions are very important in strategy games as they test the analytical skills of the player. In connection to this he mentions that the implementation of the decisions often are less important in these games unlike action games where the implementation phase often constitutes the most important part of this decision making process. The reason for this is obviously that strategy game implementations often are trivial compared to action games. To "kill" a unit in a strategy game such as Chess, Risk or Civilization is a question of moving one unit a tile in a given direction, while making a "kill" in a first person shooter involves complex hand-eye coordination and consequently far more skill regarding the implementation process.

So for now let us ignore the possible struggle related to the implementation of the decision and instead focus on the analysis process and consequently the decision itself. As mentioned earlier Heaton's model does not offer a good structural overview of how participants in a multiplayer game act. In the following figure I have modified the model so that it now includes two players playing the same game at the same time.

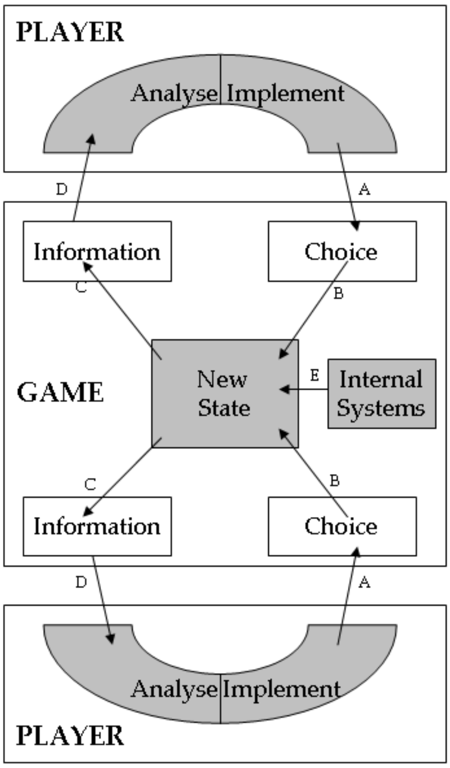


Figure 3.2: Modified 'Circular model of gameplay'

In addition to modifying the model to a two-player game I have chosen to substitute the words input and output. In my model the users communicate to the game through choices. I ignore the implementation of the choices and presume that implementations are done perfectly.

The output that the users extract from the game I have decided to term information, as this is what is needed in order to perform the analytical step in the next cycle. In this way the model does not take into account kinds of output that does not relate to the decision process.

By renaming input and output I have consequently attributed the model to a different perspective. This is done deliberately since my goal is to map the general characteristics of the analytic decision making process. The specific inputs and outputs are merely interesting as they contribute to a wider understanding of the information/choice relationship.

Based on the modified circular model of gameplay we can point out what I term "the gameplay framework". Looking at the model this framework is the entire game-block, which includes the arrows B and C. Notice the difference between these and the arrows D and A, which do not belong to the gameplay framework. Arrow D represents how the information is received by the player and used in the analytic process and arrow A represents how the decision is carried out by the player (remember how this earlier was declared rather unimportant in strategy games).

This framework is the foundation of gameplay and represents basically what is inside of the video game box you purchase at the store. This is the game or more importantly – the part of the gameplay circle that the game designer controls entirely.

My overall goal in this thesis is however to investigate if the process performed by the players between arrow D and A can be made more interesting using game theory. In order to understand this decision process it is extremely important to understand the entire gameplay framework, as this represents the entire 'world' the decision process is based on.

3.2. The gameplay framework

The goal of this section is to examine the gameplay framework that I established in the previous section.

Taking a look back on the modified circular model of gameplay I will examine the choices available to the players (arrow B) as well as how information is accessible to the players (arrow C). These arrows represent the interaction possibilities in the game and Salen & Zimmermann describe it as follows.

> "The basic unit out of which interactive meaning is made is the action > outcome unit. These units are the molecules out of which interactive designers (including game designers) create larger structures of designed interaction." (Salen, 2004)

So this action/outcome (or as I have chosen to term it; choice/information) relation is actually the building blocks used for constructing designed interaction. Notice how the words gameplay or game is not mentioned yet. The reason for this is that the action/outcome structure is so generic that it also applies to standard system development procedures and the like. This section will actually not discuss or evaluate gameplay, fun or anything that relates to video games, beside the gameplay framework, which in theory is similar to other non-game related frameworks. Think for instance about the framework behind driving a car in real life and in a video game simulation, it is the same.

Back to the structure of this chapter: After the interaction possibilities between the players and the game have been analyzed (choice and information) I will take a look at the internal game mechanics (arrow E).

This will complete my analysis of the gameplay framework. The arrows A and D will be treated in the strategy chapter.

3.2.1. A note on perspective

In the following sections I will look into the subjects' choices and information. This will be done from two different perspectives, namely a game theoretic and a player oriented perspective. The general perspective when working with game theory is focused on the overall decisions available to all players, while the perspective when analyzing video games is often centred around one player and his specific decisions.

This means that the knowledge taken from economic game theory will add to the understanding of the complete decision trees. This is supplemented by the knowledge gained from analyzing video games from a player oriented perspective. The goal of this approach is to both achieve structural as well as specific insight to these subjects.

3.2.2. Choices

Choices are the core of any game, both traditional game and video games. When a person is playing a game it is in his best interest to make the best choice possible at any given time. But what are choices in games really?

Salen and Zimmerman dissect a choice into 5 parts (Salen, 2004):

1. What happened before the player was given the choice? (internal event)
2. How is the possibility of choice conveyed to the player? (external event)
3. How did the player make the choice? (internal event)
4. What is the result of the choice? How will it affect future choices? (internal event)
5. How is the result of the choice conveyed to the player? (external event)

The internal/external events relate to whether the events are tied to internal procedures (game mechanics and such) or to the input/output procedures (interaction with the player). This section focuses mainly on the choices available to the player. The external events (number 2 and 5) will therefore not be described here, but instead in relation to information in section 3.2.3.

In connection to the five parts of a choice Salen and Zimmerman present a table showing how these parts are represented in both a traditional game (chess) and a video game (asteroids) (Salen, 2004). I have modified this table so that it includes a strategic video game (WarCraft) instead of Asteroids.

Anatomy of a choice	WarCraft	Chess
1. What happened before the player was given the choice? (internal event)	Represented by the current positions and number of the game elements.	Represented by the current state of the pieces on the board.
2. How is the possibility of choice conveyed to the player? (external event)	The possible actions are conveyed through the use of icons for each unit as well as the state of the screen, as it displays the relationships and presence of the game elements.	The possible actions are conveyed through the arrangement of pieces on the board, including the empty squares where they can move.
3. How did the player make the choice? (internal event)	The player makes a choice by clicking either an icon tied to a specific unit or by clicking on an enemy unit or the game world.	The players make a choice by moving a piece.
4. What is the result of the choice? How will it affect future choices? (internal event)	Each click will cause a change in the state of the game. Units attack, move, spawn or die.	Each move affects the overall system, such as capturing a piece or shifting the strategic possibilities of the game.
5. How is the result of the choice conveyed to the player? (external event)	The result of the choice is then represented to player via screen graphics and audio.	The result of the choice is then represented to the player via the new arrangement of pieces on the board.

Figure 3.3: Modified version of Salen/Zimmerman's anatomy of a choice comparison

Notice that part 4 is placed in the section *information*. The focus of this section is then a combination of 1 and 3, on what specific choices the player has available.

How does this concept of choice relate to game theory? Let us begin by looking at a few definitions of game theory.

Hutton describes game theory as

> "…an intellectual framework for examining what various parties to a decision should do given their possession of inadequate information and different objectives" (Hutton, 1996)

In similar fashion Dixit and Nalebuff describe:

> "Game theory is the science of strategy. It attempts to determine mathematically and logically the actions that "players" should take to secure the best outcomes for themselves in a wide array of "games."" (Dixit, 2002)

From the above quotations it seems that the goal of game theory is to determine what decisions or actions the players of a game should take. This places choice right in the core of game theory.

3.2.2.1. Choices in game theory

In game theory the concept of choice is of vital importance and any game theoretic analysis depends on the choices available to the players.

Let us have a look at the descriptions of simultaneous-move games and sequential-move games.

Bob

Alice

	Rock	Paper	Scissors
Rock	0 , 0	0 , 1	1 , 0
Paper	1 , 0	0 , 0	0 , 1
Scissors	0 , 1	1 , 0	0 , 0

Figure 3.4: Simultaneous-move game (normal form)

The event that takes the above simultaneous-move game from the beginning to the end (or from the first state to the last) is the choices made by both Alice and Bob. Said in other words the payoff cell is determined as a function of the choices by Alice and Bob.

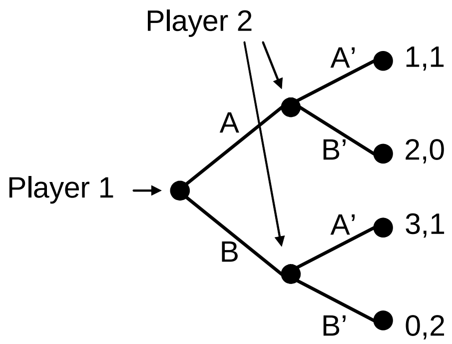


Figure 3.5: Sequential-move game (extensive form)

In the above sequential-move game the choice of player 1 takes the game from the first state to the second, while the following choice by player 2 takes it to the final state (notice how the choices are represented by the lines between the dots).

In both simultaneous-move and sequential-move games we have seen that choice is what makes the games progress. How the games progress then depend on what choices the participants make. This introduces another type of choice, the strategic choice.

Types of choices

Besides the basic choices as seen in the figures above there is also a strategic choice. This choice is obviously the choice of a strategy. Carmichael describes strategies as planned actions (Carmichael, 2005).

We could then describe the two types of choices as:

- Choice of action: The specific choice as seen in the figures above

- Choice of strategy: The choice of a set of actions

Choices of strategy then consequently consist of several choices of action. More in depth information on this is available in the strategy chapter.

3.2.2.2. Choices in strategic video games

Similar to game theory choices are a vital part of a strategic video game. Without choices a strategic video game would not be a game, so in that sense it is meaningless to question the importance of choices in this context.

When the participants in a strategic video game make choices they change the state of the game, hence making the game progress.

Just like in game theory there is however also a strategic choice in these kinds of games. Let us have a look at the two choice types in strategic video games.

Types of choices

Salen and Zimmerman write of the two choice types in video games:

> "In considering the way that choices are embedded in game activity, we look at the design of choice on two levels: micro and macro. The micro level represents the small, moment-to-moment choices a player is confronted with during a game. The macro level of choice represents the way these micro-choices join together like a chain to form a larger trajectory of experience." (Salen, 2004)

The similarity to the two choice types of game theory is obvious. An example of the micro and macro choices could be the following: A player decides to attack the enemy base (macro choice). In order to do this he needs to produce troops, so he clicks the "produce infantry unit" button (micro choice). When the unit is produced he moves it to the attack position (micro choice). He then repeats the last two steps until he is ready for the attack and then he launches the attack (micro choice). This completes the implementation of his macro choice.

In the following sections I will analyze the strategic video game Company of Heroes in order to examine what micro choices the player is facing when playing this game. The macro decisions will be examined later (3.4 & 5).

3.2.2.3. Strategic video game subject

As earlier mentioned the main video game subject of this thesis is Company of Heroes. It was released in 2006 and received global praise (Kasavin, 2006). The game builds upon classic RTS[1] features dating back to games such as Warcraft and Command and Conquer. There are however also some main differences, especially regarding the way resources are gained, which is based on how much of the map is controlled instead of a classical mine!

[1] Real Time Strategy

3.2.2.4. Analysis of micro choices in Company of Heroes

This section will look into what micro level decisions the player is facing when playing the strategic video game Company of Heroes.

Figure 3.6: Company of Heroes: Start of level

In Company of Heroes you start out with an engineer unit which has the ability to build base improvements such as barracks and other buildings that allow you to produce other military units. The engineer unit can also capture various points on the map. Controlling these points gives you an income of the various resources: fuel, munitions or manpower. There are also victory points and controlling these will make the opponents 'life points' tick down.

So the first choice is what to do with the engineer unit. Should it go and capture a victory points, a resource point or start building a building – and in either case, which!

With around 20 points in a standard map and 21 various options available to the engineer unit it is rather obvious that drawing a tree of choices equivalent to the extensive form tree quickly would get out of hand.

Instead I have chosen to focus on the different types of choices that are available in the game. By focusing on the structure of the "choice trees" I hope to discover some fundamental principles in the design of strategic video games.

Unit based choices

Company of Heroes is unit based in the sense that you can only manipulate the game world through the command of your own units. Therefore I have chosen to start my analysis with a step by step examination of the choices available to each unit in the game. The resulting spreadsheet is available on the attached CD (appendix B). I have assigned a type to each action and based on these I will categorize the various actions.

Production

The actions termed structure production and unit production are similar as they both produce units that the player can command. Below I have constructed a figure that shows the connection between unit production and structure production. It outlines where in the game the various micro choices are available.

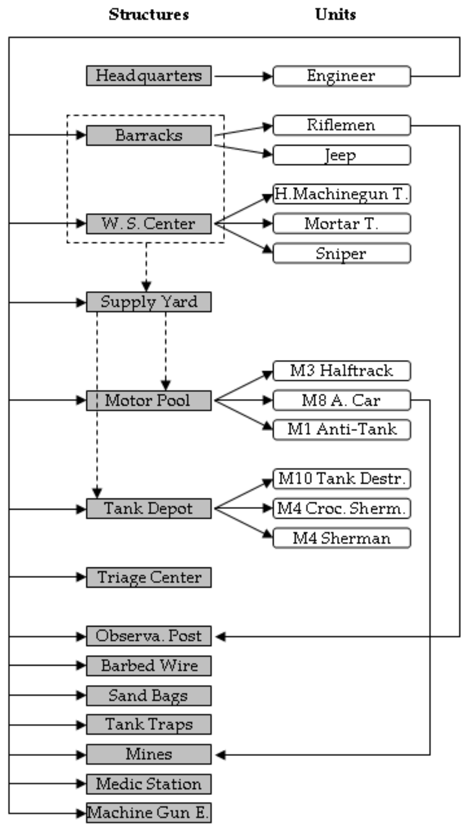


Figure 3.7: Structure of construction in Company of Heroes

The dotted lines represents prerequisites, for instance either *Barracks* or *Weapons Supports Center* needs to be built in order to be able to construct the *Supply Yard*. The fully drawn lines represent who has the ability to build what (the arrow from *Riflemen* to *Observation post* meaning that the *Riflemen* have the ability to construct an *Observation post*).

Upgrades

There are several choices in Company of Heroes that upgrade units. There are global upgrades that upgrade an entire type of units (Riflemen with BAR rifles) and some merely make specific upgrades possible (Engineers and barbed wire cutters). Regarding specific units there are upgrades that are persistent (Bulldozer) and some that are temporary (Armor piercing shells). The following figure presents when the specific upgrades are available in the game.

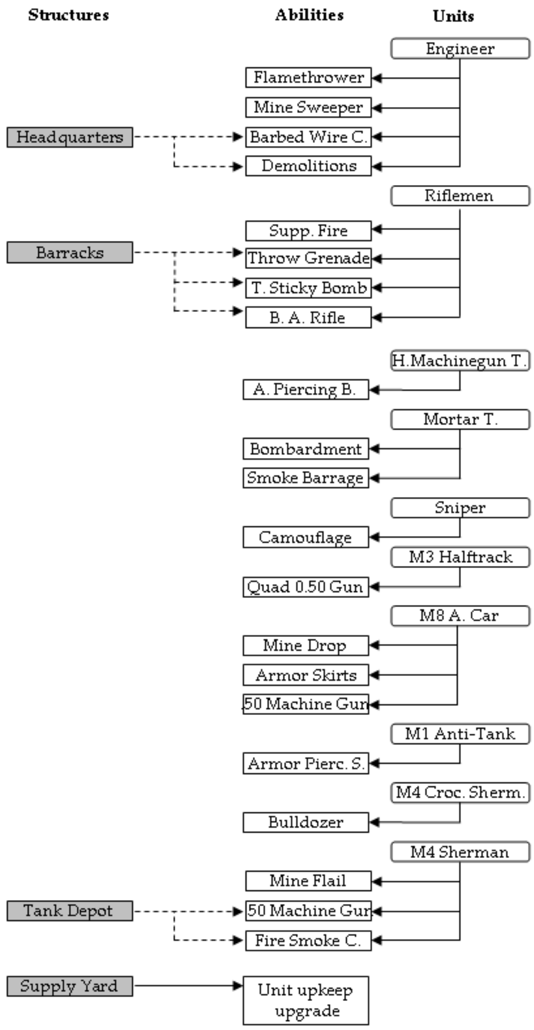


Figure 3.8: Structure of upgrades in Company of Heroes

Here the dotted lines do not only mark prerequisites but also that a specific choice has been made (an option available to the *Tank Depot* upgrades all Sherman tanks with smoke canisters). The full drawn lines indicate to what unit the ability belongs. Notice that the *Supply Yard's* ability affects the upkeep of all troops.

Territory

This section will shortly describe what micro choices are available to the player through the various units regarding the game world or territory.

First of all there are various choices available through the units themselves. These are seen on the spreadsheet mapping all the units (Appendix B). Besides the options such as attack move, retreat etc. right clicking the map with a unit selected will simply have the unit move to that spot. In connection to this right click movement-choice the map will light up in one of three different colors (red, yellow or green). These colors indicate to the player how good cover the units will be in at that specific location. The micro choices regarding movement of troops are very typical of any RTS game and should not require further examination.

Secondly certain structures in a map allows for special interaction between a unit and that structure. These are resource points, victory points and strategic points, which all are capturable by right clicking them with a unit selected. A unit can also interact with weapons and resources lying on the ground in a map. Lastly a number of neutral buildings in a map allow units to enter them for additional cover.

To sum up the micro choices associated with a unit in relation to the territory/map there are two types of choices:

- Unit based choices. These choices are generic for a unit type and except the right click-move choice these are accessed through the menu-bar of a specific unit.
- Territory based choices. These choices are associated with specific structures or items in a map. These choices can only be made by right clicking the structure or item while having a unit selected.

Non unit based choices

In addition to the previously examined unit based choices there is one branch of choices that is not based on a particular unit. The choices in this branch apply to various parts of the game and are in general hard to define. Let us have a look at it.

Commander choice/Specialization

Throughout a game of Company of Heroes one earns what is called commander points. These are very similar to what is known from other games as experience points. These can be spent to gain specialized abilities as shown below.

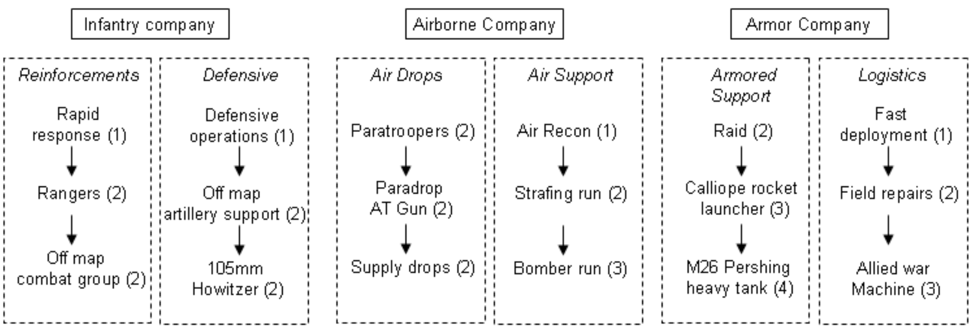


Figure 3.9: The allied commander paths

First the player must choose one of the three commander trees, Infantry, Airborne or Armor Company. Once a company has been selected the two other companies will not be available. The abilities within a company are hierarchically ordered in two lines (Reinforcements and Defensive, Air drops and Air support etc). When a company is first selected only the two top choices are available. When one of these has been bought the next ability in line is purchasable and so on.

3.2.2.5. Summary of choices

Choices are what makes games progress, both video games and game theoretic games. In both cases choice is divided into two main types: choice of action and choice of strategy. This chapter has only focused on the choices of action (see the strategy chapter for information on the other type). In Company of Heroes the choices of action are implemented in the following categories:

- Unit based choices: Production, Upgrades, Territory
- Non unit based choices: Commander/Specialization

3.2.3. Information

Looking back at a part of Carmichael's definition of game theory (from the introduction of this thesis):

> "In these circumstances the plans or strategies of the individuals concerned will be dependent on expectations about what the others are doing" (Carmichael, 2005)

And also taking a look at the definition of gameplay by Rollings and Morris:

> "…a good game is one you win by doing something your opponent did not expect and making it work." (Rollings & Morris, 2004)

Then we have a clear connection between game theory and game play. Both definitions are based on the concept of 'expecting'. Game theory is about analyzing what a given player should do in a given situation based on an expectation of what the other player is up to. Game play on the other hand seems to be about doing something that the other player did not expect. This seems to point us towards an understanding of game play as 'outplaying' or 'tricking' the rational player.

A closer look at the word 'expectation' reveals some of the key aspects of both game play and game theory:

In one sense expectation is about a lack of information, you don't know what will happen.

In another sense it is about some kind of implicit weighting of the possible outcomes, making the expected one, the one with the highest probability. This means that some information or knowledge is actually present.

So it seems that <u>information</u> available to the players is a key element in both game theory and game play. Let us have a closer look at this subject.

As Francis Bacon wrote in 1597 "Knowledge is power" (Bacon, 1597) which clearly is the case in both game theory and video games. This section will first provide a general description of the subject based in game theory and in the same instance provide a vocabulary for discussing the subject. Second the information channels in specific strategic video games will be examined.

3.2.3.1. Information in game theory

In game theory information is the foundation on which the equilibrium strategies depend. Remember how equilibrium strategies are centered on finding the best choices for a player based on an expectation of what the other player is choosing.

Types of information

Game theorists distinguish between several types or categories of information. In the following I will describe the various types of information.

- *Perfect information* is when all players know who they are playing and have knowledge of all moves made by all players. Said in other words all players know where they are in the game tree. Therefore perfect information only occurs in sequential-move games.
- *Complete information* is when all players know who they are playing and have knowledge of the current game state, when the game begins. Said in other words all players know the game matrix (as opposed to the game tree).
- Consequently *Imperfect information* is a game where the players do not have knowledge of the complete game tree and *incomplete information* is a game where the players are not fully aware of the game matrix.
- *Asymmetric information* is when all players do not have the same information, while *Symmetric information* is when all players have the same information.

In his dissertation Jonas Heide Smith (Smith, 2006) specifies games of perfect/imperfect information as games where the players are being/not being informed on every change of game state. He specifies games of complete/incomplete information as games where the players are aware/not aware of the game state at the beginning of a game.

In the figure beneath I have extended Smith's original figure (Smith, 2006, 116) describing the four combinations of the information types perfect/imperfect and complete/incomplete. I have added *asymmetric information.* The reason is that for this thesis it is important to distinguish between incomplete/imperfect and asymmetric information. Since my figure combines three kinds of information types it is not possible to visualize it using a simple matrix. Instead I have chosen to visualize it using a tree-form.

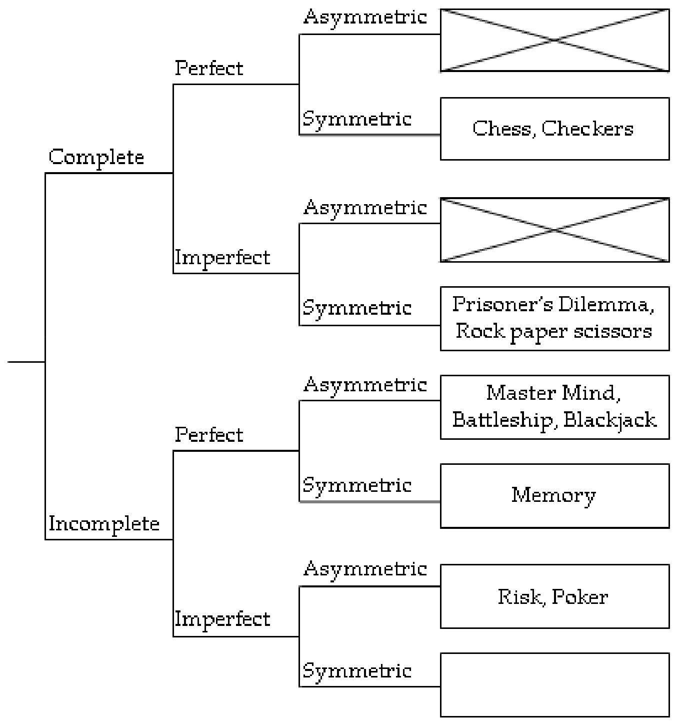


Figure 3.10: Combining the three information types (traditional games)

The figure shows examples of games that fit under the specific categories[1]. There are no games that hold both complete and asymmetric information, so that category has been crossed out. The reason for this is of course that complete information is when everyone knows everything about the game state at the beginning of the game, while asymmetric information means that not all players know everything about the game state.

Signalling and commitment

In game theory the concept of signalling is tied to games of asymmetric information and therefore also to games of incomplete information, since I explained in the previous section why no games can be of both complete and asymmetric information.

A signal is a commitment that changes the strategic situation (Carmichael, 2005). This means that a signal in game theory is only a signal when it is backed up by a commitment. When a person in a game of poker says "I got two aces" it is a free signal, hence no commitment cost. This makes the signal appear as an empty threat, while going all-in might make the threat/signal credible.

The player who sends out the signal must first evaluate the situation in order to decide whether sending out signal A or B is the most profitable.

The player who receives the signal has to decide whether to believe the signal or not. This decision is based directly on the information he has at the moment of the decision. If the

[1] I have yet to come up with a good example of a game that holds incomplete, imperfect but symmetric information.

player signalling has been truthful about his signals up until the current signal, then the odds might be that he still is. In that case the reputation of the signalling player is an important factor in this whole signalling process.

3.2.3.2. Information in video games

In this section I will identify various types of information in video games. Since these types of information are tied to specific video games I will present these information types by example screenshots from the video games. I have chosen to include examples from Civilization IV as it will complement examples from Company of Heroes in the process of showing examples of how information is conveyed in video games[1]. The specific types of information I will then connect to the theoretic types presented in the previous chapter.

Fog of war

> "The fog of war is a term used to describe the level of ambiguity in situational awareness experienced by participants in military operations" (Wikipedia, Fog of war)

As the above quotation shows, the term fog of war originates from military use. Fog of war in computer games usually refers to a situation when you can only see enemy units and/or terrain when in sight of your units. Let us take a look at a few examples.

Figure 3.11: Company of Heroes

[1] Civilization IV is usually played with more than 2 players, but the situations, in which I make use of examples from that game, might as well be from a 2 player game.

In Company of Heroes the fog of war only relates to units (soldiers, tanks) and player created structures (barracks, bunkers) and not to the level itself (the trees, civilian structures, roads). Notice in the screenshot above how the lit up circle around the three engineers marks the area where both terrain and units is visible to the player. The dark area marks the area where only the terrain is visible. An enemy garrison might be hiding in that building to the far right in the screenshot, the player can not see that at the moment.

Figure 3.12: Civilization IV: Beyond the sword

In Civilization IV not even the pre generated terrain is visible before it has been visited (the black areas in the screenshot). Beyond that the fog of war is similar to that of Company of Heroes. Notice how the tiles in near proximity of the units are lit up while the units a bit further away (out of sight) are a bit darker. Enemy activity in those squares is not known to the player, just like in Company of Heroes.

Some games, like the Warcraft series use this same 'black fog' technique. There is however an important difference. Since Warcraft has a limited number of maps the 'black fog' becomes obsolete for the veteran player as he has played the level before and therefore knows the outline of the level. Jonas Heide Smith denotes this type of information as completable (Smith, 2006, 120).

In Civilization IV the maps are auto generated which means that exploring the levels is a necessity for all players (or at least a major advantage).

In the following table the three types of fog of war are presented.

Fog of war	Description
"Complete"	Nothing is known about the area.
"Some"	Only generic features such as terrain, habitation and buildings are known.
"None"	Everything is known about the area.

Figure 3.13: The different types of fog of war in computer games

The value of fog of war is backed up by the game mechanics in both Company of Heroes and Civilization.

In Company of Heroes there are sniper units which can not be seen by most enemy units. The option to temporarily scout any area on the map using airplanes is also available. Using the terms from above, scouting an area makes the fog of war go from some to none for a limited time before it goes back to some.

In Civilization IV there are also various types of stealth units as well as a scout-options available (much like the option in Company of Heroes). In addition to that the value of having explored the map is materialized in the way that you can trade your knowledge about the map to other players. Having explored the entire map (consequently removing all complete fog of war) is in this way of the same value as money or technological progress.

This leads us to the next section which is information about enemy resources.

Enemy resources

This section will look into information regarding enemy resources such as money, technological progress, types of weapons etc.

In most competitive two player video games the private information that both players hold is of great importance. In the previous section we already saw the value of information about the map and placement of enemy units. In the following I will examine the access to information about the opponent's resources that are not visible by only looking at the map.

Figure 3.14: Civilization IV: Communication window

As seen above Civilization IV supplies more or less direct information about the opponent's resources. For instance Isabella has access to the valuable resources copper, crab, fish and gold – all resources we do not have. On the other hand we have three technologies along with a number of other valuable resources she does not have. It is also shown how much money both of us have. Notice that it is possible to trade one type of resource for another.

Figure 3.15: Civilization IV: Statistical information about opponents

To further close the gap between private and global information a rather extensive selection of graphs are also available. These graphs hold information about how the opponents develop in specific areas such as military power, production etc.

Figure 3.16: Company of Heroes: Enemy resource point

In Company of Heroes there is, contrary to Civilization IV, extremely limited information about the resources that the opponent holds. By holding the mouse over the resource points you can see how valuable a specific resource is. Based on the number of resource points the opponent holds it is possible to guess the amount of resources he or she accumulates and consequently holds. It is however extremely imprecise as the number of units and buildings produced also is hidden in the fog of war. If you see a Tiger tank coming your way rather early in the game that might indicate that the opponent has just used all his available resources to get that tiger on the map. In that way it is expectable that his or her resources are very low at the moment which might be a good time for an attack etc. It seems however that the private information is much more hidden than in Civilization IV where the game mechanics serve as the communicator of this information.

3.2.3.3. Summary of information

In game theory information is described as being incomplete/complete, imperfect/perfect and/or asymmetric/symmetric.

Strategic video games always contain asymmetric information and this is backed up by the two subjects:

- Fog of war
- Enemy resources

Fog of war is a phenomenon that is centred on knowledge of the map and consequently the distribution of units. Enemy resources are player specific and not represented on the map. In Company of Heroes there are no game mechanics that allow one player to gain information on the current resource amount of the opponent. In Civilization IV this is quite different as a wide range of game mechanics allow the players to keep track of how many resources each player has.

3.2.4. Internal game mechanics

The arrow E in the modified circular model of gameplay indicates that internal game mechanics can change the state of the game and consequently the game play cycle. This is however not the case in Company of Heroes where there is no non player interaction. An example of an internal game mechanic that could change the state of the game would be disasters/weather as known from SimCity.

3.3. Core gameplay

Having established the gameplay framework in the previous chapter I will now focus my attention towards what I choose to term the *core gameplay*. I have outlined the situation in the figure below.

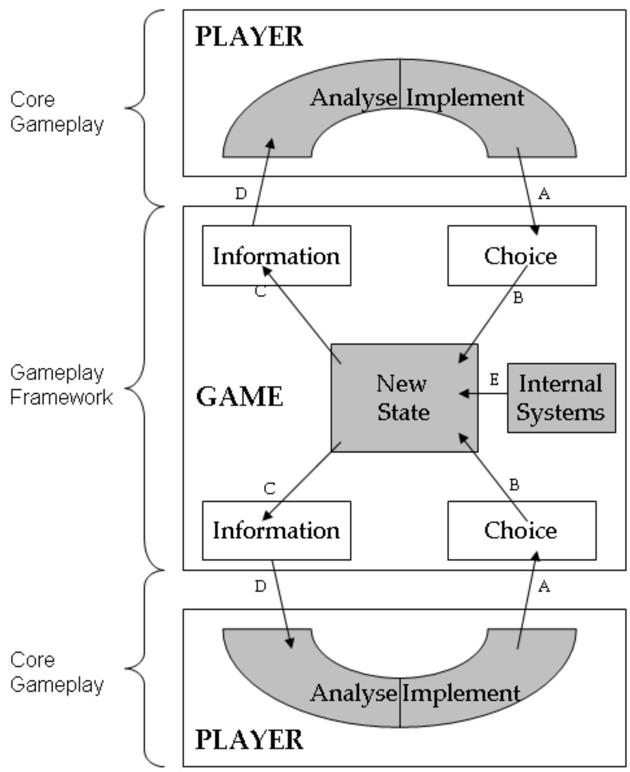


Figure 3.17: Modified "circular model of gameplay" with descriptions

I have examined the subjects' information and choice in relation to game theory on a general level. In addition to that I have described the choice and information channels that are present in the video game Company of Heroes. This should constitute a good basis for this section which mainly will consist of an examination and discussion of the relationship between arrow D, arrow A and the analysis process – all in relation to gameplay.

3.3.1. A note on approach

The approach when examining the gameplay framework was basically to group and present facts, thereby not applying any kind of interpretation. This is not possible in this chapter and the next as the main subject here is the person playing the game and he or she is obviously not made up of numbers and fixed rules. So this chapter will rely more on the human studies than technical ones.

3.3.2. Summary of the gameplay framework of Company of Heroes

In this section I will produce an overview of the results from the gameplay framework chapter. By taking the choices and information available in Company of Heroes to a higher level of abstraction it will be easier to conduct a meaningful discussion of the core gameplay associated to these subjects.

3.3.2.1. Unit based choices

Most of the micro choices found in Company of Heroes are based on units. In the following figure I have outlined how the three types of unit choices relate to the unit. Notice that both troops and buildings count as units and that not all units hold the choice of both production, upgrades and territory (buildings are not movable and some troops can not construct buildings etc).

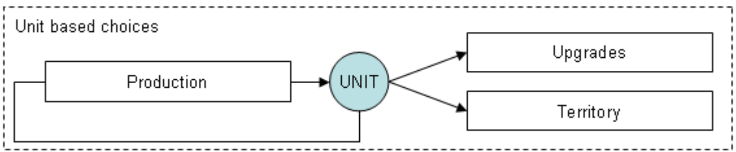


Figure 3.18: Unit based choices in Company of Heroes

The figure outlines the typical situation in RTS games where a unit can produce other units. These units can be upgraded and interact with the environment (territory).

3.3.2.2. Experience based choices

It is not possible to describe the experience based choices in a general way as the different branches are structurally different. The way the experience based choices are accessed is however very straight forward as seen below.

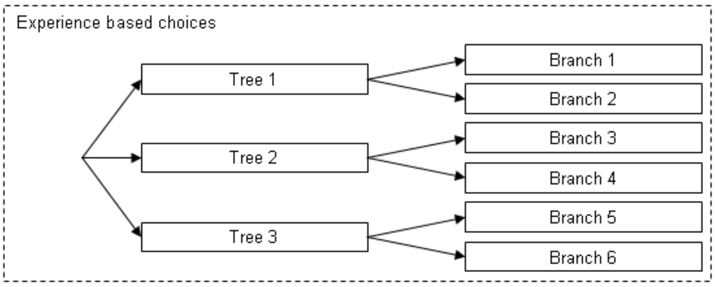


Figure 3.19: Experience based choices in Company of Heroes

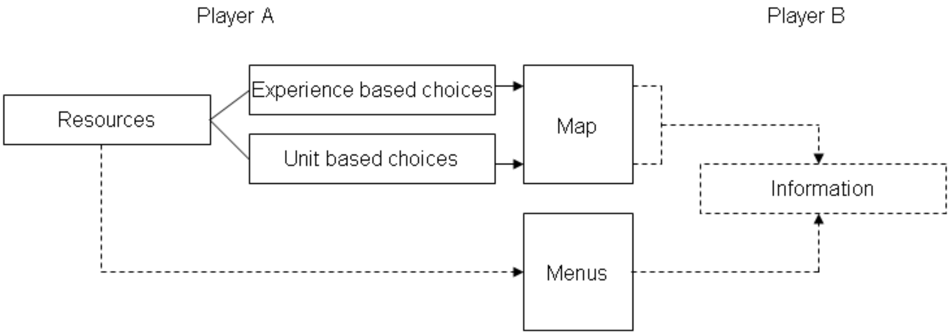
The types of choices accessed through spending experience points are:

- Production: Instantly summon special troops to the battlefield
- Upgrades: Upgrade a type of units with new abilities
- Resources: Supply the player with an instant resource boost
- Recon: Reveal unknown territory
- Bomb: Attack area
- Unit type ability: Activate a time limited ability on a specific type of units

The experience based choices thereby add new types of choices that are not accessible through units.

3.3.2.3. Information

In the following figure I have outlined the relationship between the two types of choices described above and the information the opposing player is able to gather. A number of resources are needed in order to perform most of the choices.



Notice that both types of choices are reflected in the map, which gives the other player the possibility of obtaining information about these choices (the obstacle primarily being the fog of war). In Civilization IV the players could also gain precise information about enemy resources through menus.

So in Company of Heroes all information is conveyed through the map while Civilization IV has an extra layer in which information is accessible.

3.3.3. The decision making process

Having outlined the choices and information channels in the gameplay framework we are now able to start the examination and discussion of the core gameplay. This includes how the information is interpreted and how the resulting choice is implemented. But the heart of the gameplay lies in the process that based on some input (information) produces an output (choice).

3.3.3.1. Interacting with the gameplay framework

This section will shortly describe the basics of the arrows A and D in the Modified "circular model of gameplay".

Receiving information

The player basically receives all information through his monitor and in some cases his speakers. In Company of Heroes this is more specifically done through the representation of the game world (the 3D space that covers 90% of the screen) and the menus holding both the 2D map and various buttons. A wide range of sounds also supply the player with information but let us not focus on that for now. The difference between arrow C and D in the figure is that arrow D describes the situations where the player actually gains information while arrow C merely describes that some new information is available.

Implementing choice

When information has been received and reflected upon the result is some kind of choice. Arrow A describes how this is implemented. As I wrote earlier in this thesis this situation is not as important in strategy games as in more action oriented games. Action games rely heavily on skill which refers to the implementation of a choice while strategy games rely more on the decision making process. Since this thesis is about strategy games let us then move on to this process.

3.3.3.2. Making the choice

The overall goal of this thesis is to provide insight that could assist in making the decision process more interesting hence providing a better gameplay. How this process is carried out in the human brain is however outside the scope of the thesis and to my knowledge no one has yet come up with a blueprint for the best gameplay or most interesting choices yet. Let us instead focus on what we know about this process.

First of all the game provides the player with a range of options that he has to choose among. To aid him the game also provides the player with information on choices performed by the opposing player. As mentioned earlier the process of analyzing the situation at hand and corresponding accordingly is the core of a strategy game and this is essentially where you win or lose the game. In contrast to games of coordination (platform games, shooting games and racing games) there is no real uncertainty in the implementation of the choices. This means that the best series of choices will win you the game. Notice how the word series indicate that no single choice of action will win you the game, but a series of good choices will. The word that describes such series of choices is strategy and it should come as no surprise that this word is quite central for this thesis.

3.4. Strategy

This chapter will examine the concept of strategy and its relationship to gameplay.

3.4.1. The importance of strategy

Let us begin by looking at the meaning of the word strategy and its importance in relation to gameplay.

> "A strategy is a long term plan of action designed to achieve a particular goal, most often "winning". Strategy is differentiated from tactics or immediate actions with resources at hand by its nature of being extensively premeditated" (Wikipedia, Strategy)

The above quote clearly defines strategy as being a premeditated plan of actions. This means that we are dealing with a series of actions that has been decided prior to the actions being made. But what does this have to do with gameplay?

Rollings and Morris state that "gameplay encourages the player to employ strategies" and that "all well-designed games, from Tetris to Half-Life, require the development of strategies to play them effectively" (Rollings, 2003, 39).

So what Rollings and Morris more or less say is that gameplay encourages players to use strategies because it makes them play more effectively. Notice how they point out that strategies are required in games such as Tetris and Half-Life which are not strategic games by genre. This is because applying strategy to a game is something that is done outside the game sphere. Let us dig a bit deeper into this.

3.4.2. Understanding strategy

When a person sits down to play a game he will either have prepared a strategy or not. In the case where the person has no strategy it is most likely because he has not played the game before and thus lacks the knowledge on which to build a strategy. It is likely that this player during the course of the game will come up with strategies as he learns about the gameplay framework. It could also be the case that the person is using no strategy because he is not giving any thoughts to the choices in the game. Luckily I have already stated that I presume that the player is rational and has thorough knowledge of the game. This means that the players in this thesis are thinking about each choice and are fully informed of the gameplay framework (not first time players).

So with the two basic prerequisites for employing a strategy secured we can now look into the relationship to the gameplay. As earlier mentioned a strategy is basically a plan of actions. Looking back at the modified circular model of gameplay this means that we are dealing with the core gameplay as this is where the choices (actions) are made. The word plan however points us towards the gameplay framework as this is where the thought process of making this plan derives from. In relation to the multi-player aspect of the game a strategy is carried out by one player but to some degree dependant on the other player (remember how the other player's choices alter the state of the game in the gameplay framework). In order to obtain a better overview of how strategy fits into the model I have once again altered the model.

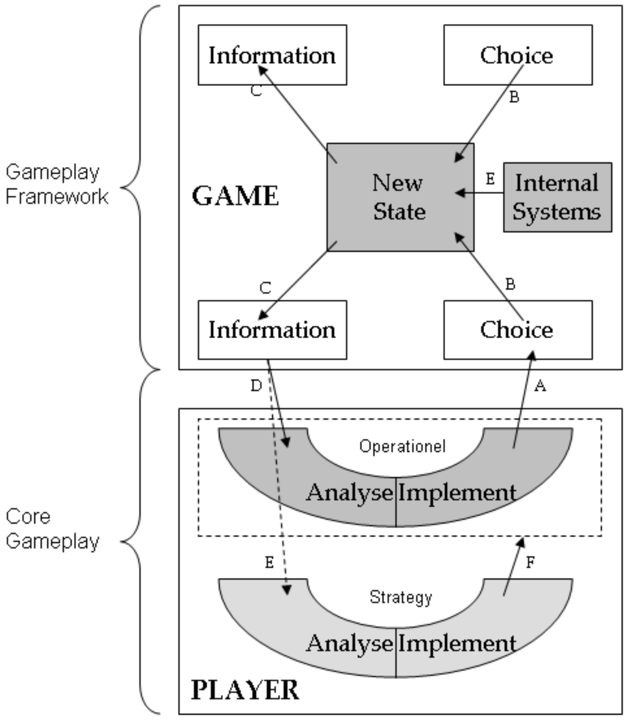


Figure 3.20: Strategy incorporated in the already modified circular model of gameplay[8]

Most noticeably I have added a second analyze/implement section termed 'strategy' and termed the original analyze/implement section 'operational'. The player will only analyze and implement on a strategy level in cases where the arrow E is triggered (marked by the dotted line). This means that the arrows D and E are structurally similar but work on different levels. By nature most new information obtained from the gameplay framework will result in an activation of the arrow D and not E. This way of understanding strategy builds on a multi-layered analytical process performed by the player. Determining when new information should trigger the implementation of a new strategy is important and the strategic choices have a greater impact on the game than the operational ones. The reason for this is that one strategic choice corresponds to a number of operational choices. The arrow F indicates the implementation of a strategy.

Let me illustrate how the model works by an example:

Player A has been creating sniper units for the last 5 operational cycles (D-A-B-C). Now he receives information from the gameplay framework that player B has fielded a jeep which is the counter unit to the sniper unit. This conflicts heavily with his premeditated strategy so this triggers him to analyze the situation on a strategy level (arrow E) in order to come up with a new strategy (arrow F). His new strategy is to merely use the snipers as

[8] To minimize the size of the figure only one of the players is shown

scouts and instead start building anti-tank units to take out enemy jeeps and upcoming tanks.

The outcome of the example situation relies on when player A understands the situation and changes his strategy. This indicates that the gathering of information about the state of the game is critical in a strategy context.

3.4.3. The role of information

When speaking about information in relation to strategy in a video game there are two main areas in which gameplay can occur:

- Extracting the information from the game world
- Obtaining meaning from the information

To illustrate the first area I introduce the model of signal transmission developed by Warren Weaver and Claude Shannon (Salen, 2004). Although used differently it can be used for understanding the situation in which one player sends a signal (about a strategy) and the other player receives it.

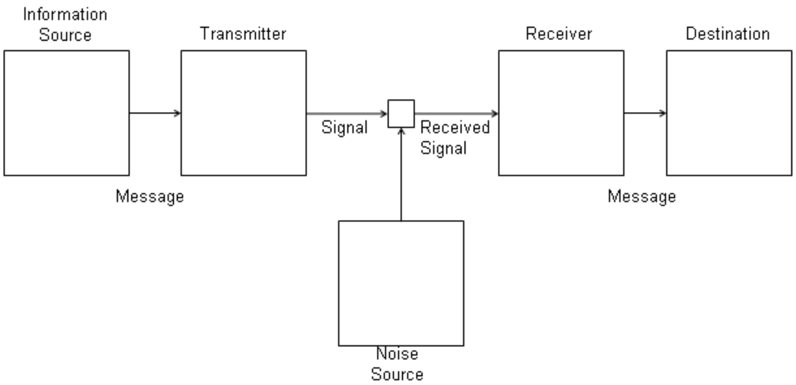


Figure 3.21: Model of signal transmission

The model was originally used in connection with types of signal transmission where the noise source was something that should be minimized, for instance a long distance telephone call. It has also been applied to situations where a speaker wants to get his message as clearly through to the receiver as possible. In these situations the transmitter of the information wanted the recipient to receive as correct information as possible. When using the model in connection to transmitting and receiving signals that hold information about the choice of strategies the exact opposite is the case.

In a video game the initiative lies on the receiving end of the transmission. This means that it is the receiver's responsibility to go and fetch potential information in the game world. This information is hidden by both noise sources and the encoding of the message done by the transmitter.

An example of such a situation could be when one player is trying to find out whether the allied player in Company of Heroes has build the Barracks as his first building. The signals that could indicate this would then be the rifleman unit and the jeep. Two factors would make this signal hard to access for the axis player. Both of the factors include the noise source which would correspond to the fog of war. First the passive ability of the fog of war would hide the respective units from the player. Second the allied player could actively move his units around utilizing the fog of war and effectively hiding the signals from the opposing player.

In some cases it might however be advantageous to actively send a signal that tricks the opposing player into thinking one strategy has been chosen when another strategy is actually being used. I will look into this subject later (5.5.3).

Theses applications of the model of signal transmissions mean that the tiny square in the middle of the model could be representing the game world. One player inserts a signal into the game world while a noise source makes this signal harder to receive for the other player. The gameplay associated with overcoming these obstacles could be termed exploratory. Notice however that this area does not include the interpretation of the signals.

Obtaining meaning from the information (area number two) is structurally quite different. It requires a more analytical approach and also a greater degree of uncertainty. When a player has received a number of signals (through exploratory actions as mentioned above) he groups these signals together and tries to form a picture of what the opposing side could be doing. This will form a prediction based on some kind of probability, hence the uncertainty.

Let me also illustrate this with an example: The player has received signals through the discovery of 3 rifleman units and that the opposing player has captured two fuel points. It is now up to the player to decide what these signals indicate. It could indicate that the other player is going for a rifleman-strategy or maybe he is going straight for the tank pool because of the fuel points? It might also be a signal deliberately trying to hide a totally different strategy? In this example the player interpretates the signals as being the result of a rifleman-strategy. This triggers the arrow E in the modified circular model of gameplay from the previous chapter.

3.5. Connection with game theory

Now we have established a framework of input/output mechanics along with an understanding of how this is used in combination with strategies. But how does this relate to game theory? The purpose of this section is to compare these mechanics with the mechanics of economic game theory in order to decide whether the use of game theory in this context deserves any justification. Notice in connection to this that I do not aim at determining whether or not gameplay can be used in combination with game theory. I purely focus on how game theory can be helpful in telling us something about the gameplay.

3.5.1. Gameplay framework: Structural similarities

Game theory provided us with two basic concepts, the simultaneous-move game and the sequential-move game and in relation to gameplay I introduced Heaton's model (circular model of gameplay). There are a number of similarities between these.

The gameplay framework with its choice, new state, information-cycles seems very similar to the cycles in the sequential-move game. In the sequential-move game one player first makes a choice which leads to a change of game state. The other player is then informed of this change of state when it is his turn to make a choice. This is also the case in the gameplay framework except for two elements.

Firstly internal systems can change the state of the game independently of the player's choices. So the similarity between the structure of the sequential-move game tree and the gameplay framework is not perfect when dealing with video games that include internal systems capable of changing the game state (notice however that Company of Heroes is not such a game).

Secondly the cycles in Heaton's model are not necessarily carried out in a perfect sequence. Some choices might be made more or less simultaneously. One player could also make several choices before the opposing player makes one. In the situations where the players make simultaneous choices there are obviously similarities to the structure of the simultaneous-move game. Notice however that the simultaneous-move game only depicts one cycle in the gameplay framework. This indicates that a combination of the two game types might be able to simulate the gameplay framework rather precisely.

3.5.2. Core gameplay

As described earlier the core gameplay is based on the analysis process that produces a choice from information, or said in other words the decision making process that the player goes through when weighting possible actions. Remembering that the goal of a game theoretic analysis is to find out what decisions a player should take to a given situation the similarities are quite obvious.

The core gameplay is the process of analyzing a situation in order to decide what to do and game analysis is generally the same. The difference is that gameplay has focus on the process while the game theoretic analysis has its focus on the result.

3.5.3. Strategy and similarities

The second layer of the decision making process of the core gameplay (see the strategy chapter) also has several similarities to game theory. Carmichael indicates these by writing:

> "When individuals have limited information about other individuals' planned actions (their strategies), they have to make conjectures about what they think they will do. These kinds of thought processes constitute strategic thinking and when this kind of thinking is involved game theory can help us to understand what is going on and make predictions about likely outcomes" (Carmichael, 2005)

Notice how Carmichael writes about "these kinds of thought processes" and that game theory can help us to understand what is going on in situations where "this kind of thinking is involved". She hereby creates the link from game theory to other similar situations. Based on the examination of the thought process involved in the core gameplay part of the circular model of gameplay I feel confident stating that the thought process of the core gameplay is included in what Carmichael described as "these kinds of thought processes".

The main reason why the strategic component of gameplay is similar to that of game theory is that they basically refer to the same thought concept. As earlier described strategy is something the players apply to the game which means that it is actually the same thought process whether you are trying to 'win' a game theoretic game or a strategic video game. Notice also how Carmichael points out that a lack of information actually is a prerequisite for this thought process. Since this lack of information is tied directly to the strategic thinking this indicates that the information in the games is fundamentally similar. Although there are striking similarities between video games and game theoretic games when it comes to strategies and the information associated to these there are also some differences. The most important difference is probably the sheer complexity of strategic video games opposed to the game theoretic ones. This results in a far greater number of possible strategies or at least a greater number of variations of strategies. This further causes a somewhat big difference to how the information is conveyed because the information channels are also more complex.

3.5.4. Summary of game theory and gameplay

As I have shown there are a number of fundamental similarities between game theory and gameplay. There are however also some significant differences.

- It seems legit to state that both the sequential-move and the simultaneous-move game technique should be applicable in relation to telling us something about the gameplay framework. In this process there are two possible sources of error: the role of the internal systems and the timing of the cycles (real time cycles as opposed to simultaneous and sequential).
- In relation to the core gameplay (the analytic process of determining the choice to make) game theory offers an analytic approach to determining the choices that should be made based on a rational understanding of the gameplay framework. This means that a game theoretic analysis will provide information about what choices the player should make in certain circumstances. This could prove useful in the process of designing or evaluating good gameplay choices.
- Examination of the strategic layer of the thought process related to the core gameplay and the strategies of game theoretic games revealed several similarities. Based on the understanding that the strategies applied to these games are basically outside the scope of the games they were found to be basically identical. The information (or rather lack of) related to these strategies was consequently also found to be identical, even though this information is conveyed rather differently in video games.

Although game theory has a somewhat different approach to the subjects that are also part of the gameplay framework, I believe the technique will be able to provide legitimate information that could enhance our knowledge on this field.

4. Applying game theory

Having examined game theory and gameplay in the previous two chapters now is the time to try and combine the two. I have performed a number of analyses (see Appendix A) and in the following I will discuss my experiences from this work. Based on the knowledge achieved I will decide next step in my work with game theory and gameplay.

4.1. Experiences

The way in which I will describe the process of applying game theory to gameplay choices is as follows.

- First I will describe the process of creating the game theoretic games.
- Secondly I will describe the evaluation and the resulting conclusions.
- Lastly I will dig into the information that these analyses revealed in relation to the process of applying game theory to situations in a video game.

4.1.1. Creating the games

My approach to applying game theory to gameplay choices was to construct game theoretic games based on situations in the video game (Company of Heroes).

4.1.1.1. Objective

The objective in this part of the analysis was to create a game theoretic game with two qualities:

- Must reflect the gameplay choices in the game. Required to achieve fundamental legitimacy in relation to telling us anything about the gameplay.
- Must contain the basic features of a game theoretic game. Required to be able to make use of game theory techniques.

The two above qualities are obviously associated to form and content respectively.

The challenge of this process was obviously to break down the complexity of the choices in the video game. This had to be done in order to construct the game theoretic game (quality number two) but without compromising the legitimacy of the game (quality number one).

4.1.1.2. Structure

When constructing the games I basically had the choice between two structures, simultaneous-move or sequential-move. Initially I used a simultaneous-move game structure to describe a gameplay choice made in the early part of the video game. It quickly became clear that this structure was too simplistic and really only usable when examining very basic gameplay decisions. To be able to describe the more complex and also more interesting gameplay choices I had to work with the sequential-move game structure. One of the features of the sequential-move game is that it is able to depict a sequence of choices. This gave me the opportunity to construct a game based on a series of gameplay choices. Although much more usable the structure of the sequential-move game introduced more problems in relation to how it is able to reflect the situations in the video game (quality number two in 4.1.1.1). The main issue was how to reflect real time choices in a sequential-move game.

4.1.1.3. Assigning payoff values

The far most important feature of a game theoretic game is the payoff values. These are the foundation of any game theoretic analysis and assigning these values involved several complications. This process is purely oriented towards how the game reflects the gameplay choices in the video game (quality two in 4.1.1.1). No matter what payoff values are chosen it is possible to conduct game theoretic analyses based on these. But if the values do not reflect the true value within the video game, then the results from an analysis will be worthless.

4.1.2. Evaluating the games

Looking back at the objective section (4.1.1.1) I presented two required qualities of the game theoretic games. Do the games created have both qualities and to what degree? I will answer this question by taking a critical look on the games I came up with.

4.1.2.1. Quality I: Form

All the games created possess the quality of form, meaning that they have all the basic features of a game theoretic game. This means that the tools associated with game theory are usable to analyze the games created. The value of analyzing the games is however based on how well the content matches the choice situations in the video game.

4.1.2.2. Quality II: Content

While constructing the games I gave a lot of thought to how well the games depicted the situations in the video game. In the following I will sum up these thoughts.

Game of units: Analysis of how units match up against each other

In this game I identified two main problems:

- All of the payoffs related to the same type (infantry) which effectively meant that the choices of the opponent did not matter. This resulted in the presence of a dominant strategy for both players.
- The payoff values only related to the damage output of the units. Abilities such as stealth and speed were not included.

Although both problems are related to the payoff values it seems that problem number one is also related to the form of the game. The reason for this is that there is no strategic interdependence (Carmichael, 2005) meaning that the players do not care what the other player is doing. So although the game structurally is a correct game theoretic game there is a fundamental problem in how I determined the payoff values. Based on how the video game calculates the damage this was however the best representation as the video game does not differentiates the damage in a more specific type based way.

The second problem is also based on the payoff values but with another perspective. The problem here is centred on the fact that the payoff value is primarily based on the damage output. This is another example of a problem where I did not see any real alternatives because how do you weight abilities such as stealth and speed in comparison with damage output and other factors. I felt that the only legitimate way of determining the payoff values had to be done based on a factor that I could retrieve from the game itself hence a number. This however automatically raises a question about the value of such a game.

Although the game theoretic game I came up with is a perfect representation of the video game this is of very little value as it only takes into account one attribute meaning that it effectively can only tell us about a technical relationship between the units.

So when determining the payoff values in this game I was in a dilemma. I could either represent the payoffs by mathematical calculations based on numbers from the game (which could question the value of the game) or I could make estimations of the utility of the units based on a qualitative analysis of the game (which could question the legitimacy of the game and consequently the value).

Game of location: Analysis of the battle for a specific location

In this game I also identified two problems:

- Describing complex chains of choices in a sequential-move diagram is not really doable.
- The choices are basically tactical and not strategic.

I started out creating a simultaneous-move game, but the one move nature of this type of game limited the quality of representation because the video game is played in real time. By also creating a sequential-move game I could depict more choices hence improving the quality of representation. The main problem here is however that adding choices causes an exponential growth in the size of the game tree. So adding more and more choices with the intent of upping the quality of representation is only an option in theory.

The other main problem I stumbled upon was the fact that the choices actually were more tactical than strategic. Although both tactical and strategic choices belong to the type of choices that are created in the minds of the players there is an important difference. In the strategy chapter I described how strategic choices relate to operational choices (that one strategic choice is carried out by performing a number of operational choices). Tactical choice is located in between which means that a strategic choice cause several tactical choices which cause several operational choices. The reason why this is important is that tactical choices based on this are more closely associated to the operational choices.

Game of territory: Analysis of the battle for the various resource points in a map

In this game I chose not to fully construct the game because knowledge from the previous games clearly indicated that I would stumble upon three already known problems. The three problems were:

- The complexity of the payoff tree would cause it to be incomprehensible
- Similarity in payoff values would devaluate the resulting equilibrium
- The game only takes into account one factor consequently excluding a number of factors which results in errors in relation to how it describes the video game situations

The first problem is directly tied to the effectuation of the situation discussed in the previous game about how complex choice chains were not really describable through the payoff tree of a sequential-move game.

The second problem relates to the fact that the map and the distribution of resource points are mirrored so both players have the same choices and the same payoffs. This would result in a rather dull dominant equilibrium strategy for both sides.

Purely looking at the choices associated to the map resulted in a problem of the same category as the second problem in the game of units. Although it might be a correct representation of choices, if they were to be made based on one factor. Unluckily this is not the case which means that this game would offer little usable information.

Game of production capacity: Analysis of production capacity

In the game of production capacity I identified one problem which once again relates to the payoff values. I came to the conclusion that I could not justify associating a payoff value to a number of the choice combinations. The reason for this was that the payoffs of the choices were highly dependant on external circumstances. An example of this would be in a penalty shootout. What payoff should a kick to the left force? And what about a kick to the right? This is obviously extremely dependant on the position of the goalkeeper. I was in a similar situation when creating this game and decided to only state a payoff in situations that generally would benefit the player.

This lack of payoffs basically made the game theoretic game worthless, at least in the sense of applying game theoretic techniques such as calculating equilibrium strategies and so on. The structure however revealed some interesting information. I discussed two main subjects in connection to this and in the following I will sum up the results of these discussions:

- Imbalance due to the lack of knowledge for the axis player
- Sequential-move or simultaneous-move game?

The first discussion was based on the fact that the axis player can built only one building when the game starts while the allied player has the choice between two (buildings that can produce troops). This could indicate that the allied player started the game with the upper hand because he would know exactly what kind of units the opposing player could field. In the specific game this meant that the first choice the allied had to make was an informed one and the first choice the axis player had to make was not. But based on how the information was distributed in the game this could change. If the axis player for instance saw one of the allied player's units, then he would know what kind of initial building he was up against. This would totally change the situation. The conclusion of the discussion was that it could not be determined who had the upper hand but that it highly depended on the degree of information the players would have at the time of the decisions.

The second discussion was also on the subject of information but with another perspective. Although constructed as a sequential-move game the extensive use of dotted lines depicting more or less uninformed choices indicated that the specific choices were of the same nature as the choices in a simultaneous-move game. The interesting point being made here is that the choices in the video game are sometimes sequential (informed) and sometimes simultaneous (uninformed).

4.1.3. Lessons learned

What information did the work with creating game theoretic games offer? In this section I present the main subjects based on the evaluation of the games.

4.1.3.1. Assigning payoff values

In relation to the payoff values I have divided the problems into two groups:

- Basic problems
- Representational problems

The basic problems relate to situations where the lack of structural dependencies renders the game useless. This reminds us about the game theoretic fundamental principle about strategic interdependence (Carmichael, 2005). Leaving out this critical principle will result in some kind of decision tree that would not be very interesting for this thesis. The reason for these basic problems furthermore seems to be present only in cases where non strategic situations are attempted mapped onto a game theoretic game. Said in other words it might be impossible to successfully construct a useful game theoretic game from low level situations in a video game, but this does not mean that the same would be the case for situations of higher level.

The representational problems on the other hand apply to the entire process of constructing game theoretic games based on video games. These kinds of problems relate to how an outcome in a video game is transformed into a numerical payoff value.

I have tried to approximate the video game outcome by simplifying it to a few factors. This approach removed the possibility that external factors (besides the degree of representation) would influence the conversion. This however resulted in such a bad representation that the results of a game theoretic analysis based on these payoffs were worth very little.

I also took the other approach which meant accepting that factors such as personal interpretation and judgment would occur in order to achieve a better degree of representation of the situations in the video game. This approach introduced other problems, most significantly in regards to the sheer difficulty of actually determining these payoffs. Although the purpose of this approach was to achieve a better representation this was not necessarily the case.

The lesson learned regarding the payoff values is that it might be impossible to achieve good representational payoff values by calculations, but it is also extremely difficult to achieve good representational payoff values by interpreting and judging – and do not forget the importance of strategic interdependence.

4.1.3.2. Complexity

When constructing game theoretic games with more than a few sequential choices the size and complexity of the games basically rendered them useless. As earlier mentioned this is because the number of final states rises exponentially based on the number of choices. This limited the number of choices a game could include and this was especially a problem for the games of lower level where a lot of choices are necessary to form a coherent whole. It went a bit smoother on the game situations of higher level where the few choices better represent what is going on in the video game.

This seems to indicate that it is not possible (or does not make much sense at least) to directly map choices from a video game onto a game theoretic game in cases where the number of choices is high.

4.1.3.3. Choice types and information

Unlike the two previous subjects, focusing on the structure of the games revealed some valuable information. This information falls into the following categories:

- Game balance
- Choice types and player influence

We saw how initially giving one choice to one player and two choices to the other player did not necessarily favor either. The reason for this was that the advantage of the situation was based on information. This is an example of game balancing that does not simply has its foundation in mirroring the choices, which was the case in connection to the map layout for instance. The key word here is information and the interesting point being the fact that information despite its abstract form is given a real value in this situation.

Information is also essential when determining the type of a specific choice. Strategic video games consist of a number of choices. These can be carried out either simultaneously or sequentially. The interesting part is however that the informational relationship between the players is actually often the determining factor in what kind of choice we are dealing with. This once again places the concept of information in a central role, not just on an analytical level but also when actually playing the game.

Regarding information the lesson learned is that despite uncertainty about the actual payoff values and the actual structural representation of the games there is evidence pointing us towards an understanding of information as not just an important part of gameplay and game theory, but as perhaps the most important subject overall.

4.2. Further work: Now what?

In this section I will reflect upon the information presented in the previous chapter in order to determine how to move on from here.

4.2.1. Focusing on strategic choices

Applying game theory to situations in which the choices are non strategic has revealed several flaws. In connection to this one could think that this conflicts with the non strategic choices in games such as the prisoners' dilemma which clearly is a game theoretic game. This is however not the case as we are dealing with two different situations.

In the prisoners' dilemma the choices 'deny' and 'confess' represent meaningful actions in relation to the real life situation the game is supposed to depict. What my analyses have shown is that in order to gain the same degree of meaningfulness when depicting situations in a strategic video game the actions (in the game theoretic game) must represent strategic choices (in the video game). So the flaws I identified relates to the construction of the game theoretic game and not to how the game theoretic analysis is carried out.

Based on the above I have chosen to only focus on analyzing the strategic choices in a video game through the use of game theory. Notice how this does not change anything in relation to the legitimacy of the game theoretic techniques and methods. It only affects the way the video game is reduced to a game theoretic game.

4.2.1.1. A structural overview

The structural relationship between the choices in a video game and the choices in the corresponding game theoretic game is outlined in the following figure.

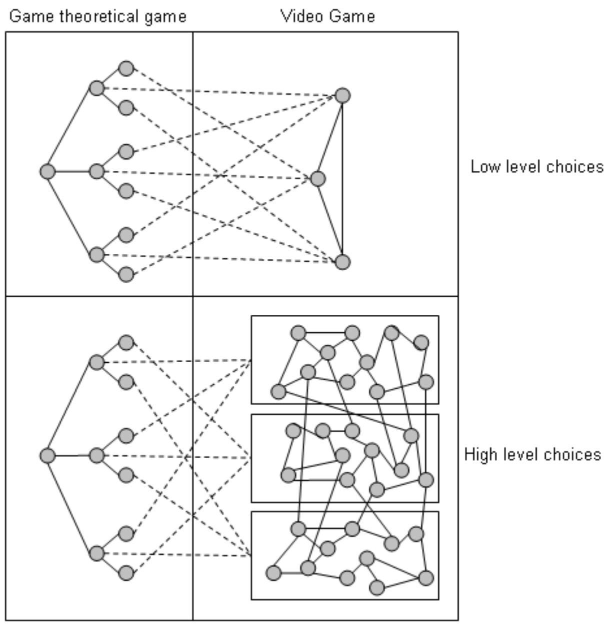


Figure 4.1: Difference between low level choices and strategic ones

The resulting game theoretic game is structurally the same which means that my decision to only focus on strategic video game situations in the video game does not change the game theoretic approach.

It does however significantly affect both the process of constructing the game theoretic games and the type of knowledge that is attainable from analyzing the constructed game theoretic game.

4.2.2. Complexity handling

By only mapping strategic choices from the video game solves one of the problems found earlier. Presuming that the number of strategies is far smaller than the number of operational choices this will reduce the size and complexity of the game trees. Let us take a look at the consequences of this.

Seen from a game theoretic point of view there is no problems associated with reducing the size of the game tree. Most game theoretic games are actually significantly smaller in size (Prisoners' dilemma, Centipede game (Malkevitch, 2007)) than the games I created earlier. Based on the number of applications about these well known game theoretic games indicates that the size of the game tree does not necessarily impact the complexity involved in analyzing the situation.

From the perspective of the video game it is however a bit more complicated. The approach of only focusing on video game strategies in the game theoretic games means that:

- Low level choices and their internal connection are partially ignored
- It will be possible to focus more on the strategic interdependence
- The representational quality lies outside the framework of the game theoretic game

4.2.2.1. Low level choices

When focusing on strategies only those low level choices that are important on a strategic level are included. This means that the result of the game theoretic analysis will not hold any information about how low level choices correspond to each other. So if the intend is to analyze how often it is relevant to purchase the Bulldozer upgrade for the Sherman tanks then this is definitely not the way to go. I am however aiming to examine the general gameplay choices in relation to winning the game and in this case this approach seems appropriate.

4.2.2.2. Strategic interdependence

The focus on strategies makes it possible for the game theoretic analysis to say something about the earlier mentioned strategic interdependence (the fact that the choices made by one player affects the payoffs of the other player and vice versa).

4.2.2.3. Representational quality

With the new approach the biggest difference when constructing the game theoretic games is how to determine the strategies. When mapping choices of lower levels it was possible to base both the choices themselves and the associated payoff purely in the game mechanics of the video game (which although caused several other problems). The complexity involved in the construction of strategies makes it impossible to determine the strategies present in the same way. This closely relates to the concept of emergence in video games. Jesper Juul describes this as:

> "Game type where variation appears by the interaction between elements in the game. Emergence games often surprise players and even the designers of the game. (Juul, 2005)

Since these kinds of games are not designed to have a fixed number of specific strategies I see it as a necessity to include knowledge gathered in relation to actually playing the game.

In connection to this it is a fortunate fact that the abstract concept of strategy is one that most strategic video game players are well aware of. Strategy is an embedded part of any online community based on a strategic video game. This has several advantages:

- Strategies are well defined packages (through extensive discussion between players)
- The weighting of strategies in relation to power or effectiveness is a critical part of winning the video game and is therefore also thoroughly debated on the internet

This basically comes down to the fact that there is latent knowledge in the community specifically about strategies, both about the structure but also about the relative power of these. These strategies are discussed daily on various forums which strengthens the assumption that these strategies are a good representation of how people play the game.

4.2.2.4. Summary of connection to earlier problems

In this section I will shortly summarize how the problems I stumbled upon earlier will be removed, minimized or altered by only applying game theory to strategic choices.

The basic problems will be removed because the nature of strategies in a two player strategic video game ensures strategic interdependence.

The nature of the representational problems will be different because the difficulty will lie in transforming information gathered through qualitative methods into game theoretic choices (opposed to transforming information gathered directly from the game into game theoretic choices).

The complexity problems will be minimized because depicting the entire video game will require significantly fewer game theoretic choices – because these choices represent entire strategies and not single low level choices.

5. Hands on: Strategy and information

Based on the knowledge gained through the previous chapter the focus will now entirely be on the strategic choices in Company of Heroes. The construction of the game theoretic games is as already mentioned a bit different than earlier in relation to strategies and representational quality.

5.1. Method

The process of constructing the games of strategy relies more on feedback from individual players of Company of Heroes than earlier, where I constructed games from the numbers more or less directly retrieved from the game. This calls for a change in method and my 'strategy' is as follows:

- Gather information on all possible strategies from capacities within the Company of Heroes community
- Define a suitable number of strategies based on a comparison of the retrieved feedback
- Gather information on the relative power of these strategies (Simultaneous-move game)
- Construct a sequential-move game based on the retrieved feedback
- Gather information on the sequential-move game with focus on how information affects the choice of strategy

The objective of this method is to achieve a high representational value. Every time information is processed (and hereby reduced in complexity) the next step is gathering feedback from the people representing the Company of Heroes community. This should reduce the risk of badly interpretating the information and consequently securing a good representation of the video game. This however heavily relies on the competency of the people involved.

5.2. The players

In the process of creating the game theoretic game of strategy in Company of Heroes I more or less blindly rely on the information supplied by a group of individuals representing the community associated with the game. Therefore the process of selecting these people is quite significant.

5.2.1. Finding good representatives

In connection to my prior research (in relation to retrieving numerical values directly from the game) I contacted the site director of "Planet Company of Heroes" Tyler Rowe[9].

[9] http://planetcoh.gamespy.com/static.php?page=staff

He eventually recommended me to take a look at the people at "Game replays"[10].

Here I contacted all the people that could have extended knowledge on the strategies of Company of Hero. This was obviously primarily the "Strategy specialists" but I also contacted several "Map reviewers", "Game moderators", "Game casters" and "Game administrators". I received several interesting replies and noticed how three or four people told me to speak to an individual by the name of George Channing. He is the sites "senior strategy specialist" and apparently one of the most knowledgeable players around. Based on the quality of the replies and the number of recommendations from other players I focused on a group of five people to represent the Company of Heroes community.

5.2.2. The representatives

In the following I will shortly describe the five representatives. The names in brackets are their gaming nicks.

5.2.2.1. George Channing (12azor)

Achievements: Finished 3rd in the first season of CoH and received 3rd place prize for Allied rankings. Top 3 Allied from version 1.4-1.7. Highest number of wins as Allied in the period version 1.4-1.7. Currently top 10 US and Wehrmacht[11]. Written 6 guides and participated in 8 replay of the week on gr.org and one gold replay[12].

Role at game replays: Senior strategy specialist

5.2.2.2. Wyatt Kopka (General Grant)

Achievements: Played both allied and axis. Top ladder spot was 68.

Role at game replays: Senior Discussion Moderator (and occasional contributions in the strategy section)

5.2.2.3. Steven Uray (Surprise)

Achievements: Placed 2nd in the online ladders with two factions (Allied and PE[13]). Placed 1st and 2nd in the last two tournaments and won a total of $1000 from CoH.

Role at game replays: Strategy moderator

5.2.2.4. Jason Heck (RabidRacoon)

Achievements: Top 15 allied player. Host of the gamereplays.org strategy cast[14]

Role at game replays: Strategy specialist (and shout caster)

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[10] http://www.gamereplays.org/community/index.php?&act=staff&CODE=show&ga_id=25
[11] In the new expansion Opposing fronts.
[12] Refers to the quality of the games
[13] Opposing Fronts faction
[14] High-end strategy chat show

5.2.2.5. Evans Boney (Bonedog)

Achievements: Invented the pioneer spam strategy and was top 100 with both allied and axis in 1.7-1.71.

Role at game replays: Strategy specialist

5.3. The strategies

5.3.1. Gathering information: Strategies

As earlier mentioned I requested a list of the strategies being used in Company of Heroes (version 1.7). This resulted in a lot of feedback of varying quality. Some were explaining every strategy thoroughly and some only presented one or two strategies. I discarded the feedback that was too simplistic and the feedback that was on a lower level of abstraction (unit to unit and map-specific).

5.3.2. Identifying representational strategies

In an excel-document[15] I typed in all the strategies presented by specific players. Then I compared the strategies and placed similar strategies in the same row. This can be seen in Appendix B. I selected the representational strategies as the ones proposed by at least two players. This resulted in five strategies for each side.

5.3.2.1. List of strategies

Allied strategies

- Riflemen + Quads + Armor company
- Riflemen + Airborne company
- Riflemen + Weapons Support Center + Airborne company
- Riflemen + Tier 4 + Airborne company
- Riflemen + Rangers

On a side note this seems to indicate that the choice of opening building discussed earlier (4.1.2.2) in fact is not much of a choice after all.

Axis strategies

- Tier 2 + Terror company
- Tier 3 + Pumas + Blitz company
- Tier 3 + Blitz company
- Pioneers + Blitz company
- Tier 2 + Tier 3 + Defensive company

[15] See Appendix B

On another side note this indicates that the exclusion of the choice of going straight to Tier 4 that I performed earlier was legitimate (8.3.6.1).

5.3.3. Gathering information: Relative power of strategies

Channing (12azor) provided the information about the relative power of the strategies. He simply filled in a table with allied, axis or 50/50 indicating which side the strategic match up would favor. In addition to this we discussed two of the strategies which resulted in the removal of an allied strategy, because it was not really a different strategy, just a variation of one of the other strategies.

5.4. The games

5.4.1. Simultaneous-move game

Based on the identified strategies and the relative power of these obtained from Channing I have constructed a simultaneous-move game:

	T2+Ter	T3+Pum+Bli	T3+Bli+Rush	Pio+Bli	T2+T3+Def
Rif+Qua+Arm	50/50	50/50	Allied	Axis	Axis
Rif+Air	50/50	Allied	Allied	Axis	Axis
Rif+WSC	Allied	Axis	Allied	Axis	Allied
Rif+T4+Air	Axis	Allied	Allied	Axis	Axis
Rif+Ran	50/50	Allied	Allied	Axis	Allied

Figure 5.1: Simultaneous-move game of strategy

The simultaneous-move game has both a dominated and a dominant strategy. The dominant strategy is obviously Pio+Bli and the dominated strategy is T3+Bli+Rush. Channing explains how the Pio+Bli strategy dominated the game before the expansion pack[16] and that the T3+Bli+Rush strategy was mainly used against beginners.

As a consequence of this I have decided to remove both of these strategies from the simultaneous-move game which results in a final simultaneous-move game that looks like this:

[16] This thesis is analyzing the final version of the original Company of Heroes (1.71). The expansion mentioned is called Company of Heroes: Opposing Fronts

	T2+Ter	T3+Pum+Bli	T2+T3+Def
Rif+Qua+Arm	1,1	1,1	0,2
Rif+Air	1.1	2,0	0,2
Rif+WSC	2,0	0,2	2,0
Rif+T4+Air	0,2	2,0	0,2
Rif+Ran	1,1	2,0	2,0

Figure 5.2: Final simultaneous-move game of Strategy (Channing)

Removing the dominant and the dominated strategy leaves us with the above simultaneous-move game. The Rif+Ran strategy seems to offer the allied player a significant advantage, but Channing explains that this strategy was only used by the top players and required a lot from the player. I will return to this subject later in the discussion.

Notice that I have also transformed the payoffs into numerical values, which clearly shows that the game is a constant sum game which all games of pure conflict are (Carmichael, 2005, 7). I believe that 0, 1 and 2 are legitimate representations of the situations in which you have the disadvantage, no disadvantage or advantage and advantage.

5.4.2. Sequential-move game

The simultaneous-move game produced an overview of how the different strategies match up against each other but it only includes one choice per player and these choices are required to be simultaneous, which means uninformed.

5.4.2.1. Size and structure of the game

To better depict the situation in the video game I have chosen to construct a sequential-move game with two choices per player. There are two reasons for this:

- The game mechanics generally make it impossible to change strategy more than two times. The main reason for this is that the choice of commander is final and can not be changed (and is a critical part in most of the strategies). The only place where more than two choices could be present is in a situation where the allied player cycles through the various strategies that make use of the airborne commander.
- The above reasoning is backed up by Channing who points out that people would not change the following strategies:
  - T2+Ter
  - Rif+Ran
  - Pio+Bli

- o Rif+T4+Air

  It is game mechanically possible to change the last two mentioned strategies, but the fact that Channing states that this is not something anyone would do, further indicates that two choices is suitable for a good representational sequential-move game.

In relation to the structure of the game I have decided to make use of the dotted lines[17] again to indicate that all the choices in the game are not informed by default. This will be heavily discussed in the following chapter, Information.

5.4.2.2. Constructing the game

First I constructed the game tree in such a way that all game mechanically possible choices were present, meaning that I initially only excluded the choices that involved changing commander, which as earlier mentioned is not possible. I then received feedback from Channing about the natural changes in strategy. He clearly stated that the four strategies mentioned in the prior section would not be changed so I removed all these choices as well. This lead to a reasonably sized sequential-move game tree that however is slightly dull for the axis player as there are no real second choices for him.

Based on whether the player changes strategy I have introduced more payoffs. The reasoning behind this is that it is a more favorable situation if one does not have to change the strategy. This results in six different payoffs and I have chosen to represent these by letters instead of numbers as the importance lies in the relative utility of the payoffs. The utility function for both players is: A > B > C > D > E > F.

[17] The dotted lines will in fact not be present in the figures visually as it removes the overview of the figures. Just imagine dotted lines between all the choices.

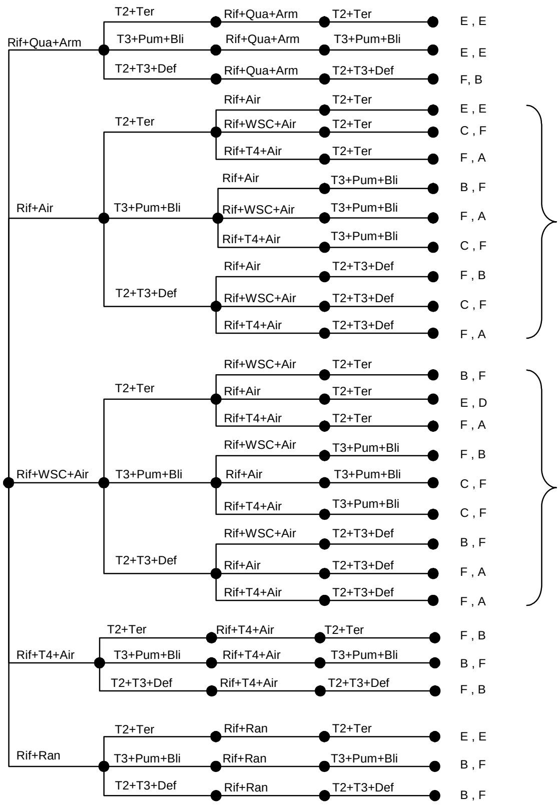

Figure 5.3: The sequential-move game of strategy[18]

Notice how the allied player can choose either Rif+WSC+Air or Rif+Air and still maintain the same choices. It is actually only in these situations that the second choice plays any role, so if it had not been for these two, then the simultaneous-move game had been sufficient in depicting the game situations.

5.5. The information

The sequential-move game is characterized by the high number of dotted lines, indicating uncertainty for the decision maker about what state the game is in. The interesting part about this is however that information can change this uncertainty and this is the main subject in this chapter. Before digging deeper into the uncertainty I will perform a typical game theoretic analysis of the two games of strategy I created in the previous sections.

5.5.1. Analyzing the games

5.5.1.1. Perfect information

Let us for a moment think of the sequential-move game as having perfect information and let us then find the solution using backward induction. Backward induction is a technique used to solve extensive form games (sequential-move games) of perfect information (Stengel, 2001). Stengel and Turocy describe the technique in the following way:

[18] Imagine dotted lines between all choices (actually drawing these would mess up the overview of the figure)

“It first considers the moves that are the last in the game, and determines the best move for the player in each case. Then, taking these as given future actions, it proceeds backwards in time, again determining the best move for the respective player, until the beginning of the game is reached” (Stengel, 2001)

In the following figure I have performed this analysis, by marking the best choices with a bold line:

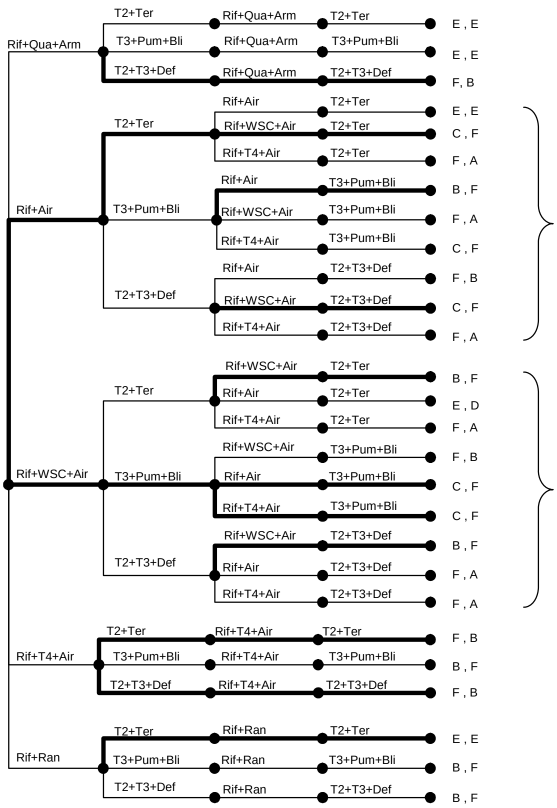

Figure 5.4: Backward induction performed on the sequential-move game

This analysis shows that the game will result in the payoff C for the allied player and the payoff F for the axis player. Notice also how two of the initial choices by the allied player will result in this payoff.

Solution

This analysis shows that there is only one possible outcome of the game and this outcome favors the allied player. But remember that this was with the assumption that the game had perfect information which is luckily not the situation in Company of Heroes.

But what if the decision making process involved imperfect information? This situation is what the simultaneous-move game I created earlier depicts so let us analyze that one. There is however a slight difference because the sequential-move game takes into account more choices than the simultaneous-move one. I however characterize this as a slight variation as the payoffs generally are the same.

5.5.1.2. Imperfect information

I have underlined the best choices in the simultaneous-move game below:

	T2+Ter	T3+Pum+Bli	T2+T3+Def
Rif+Qua+Arm	1,1	1,1	0,2
Rif+Air	1.1	2,0	0,2
Rif+WSC+Air	2,0	0,2	2,0
Rif+T4+Air	0,2	2,0	0,2
Rif+Ran	1,1	2,0	2,0

Figure 5.5: Simultaneous-move game of strategy

As seen above the pure strategies do not constitute a Nash equilibrium and consequently there are no dominant strategies. Instead we will have to look into mixed strategies.

First I have removed all the weakly dominated strategies (2.4.2) which results in the following game:

	T2+Ter	T3+Pum+Bli
Rif+WSC+Air	2,0	0,2
Rif+Ran	1,1	2,0

Figure 5.6: After removing weakly dominated strategies

In order to find the equilibrium of the game it is necessary to perform a series of calculations in order to determine how often the different choices should be made.

Calculations

Let us first look at the game from the perspective of the allied player:

Px is the probability that the axis player chooses T2+Ter

Allied player's expected payoff from choosing Rif+WSC+Air = px2+(1-px)0

Allied player's expected payoff from choosing Rif+Ran = px1+(1-px)2

Setting these equal each other yields:

Px2+(1-px)0 = px1+(1-px)2, or

Px = 2/3

This means that if the axis player chooses T2+Ter with probability 2/3 then the allied player should play a mixed strategy.

Similarly let us perform the same calculations for the axis player:

Pa is the probability that the allied player chooses Rif+WSC+Air

Axis player's expected payoff from choosing T2+Ter = Pa0+(1-pa)1

Axis player's expected payoff from choosing T3+Pum+Bli = Pa2+(1-pa)0

Setting these equal each other yields:

Pa0+(1-pa)1 = Pa2+(1-pa)0, or

Pa = 1/3

This means that if the allied player chooses Rif+WSC+Air with probability 1/3 then the axis player should play a mixed strategy.

Solution

The above calculations show the game's mixed strategy Nash equilibrium. This equilibrium is writeable as {(Allied: Rif+WSC+Air; 1/3, Rif+Ran; 2/3)(Axis: T2+Ter; 2/3, T3+Pum+Bli; 1/3)}.

When selecting the initial strategy the allied player should then select Rif+Ran 2 out of 3 times and Rif+WSC+Air 1 out of 3 times while the axis player should choose T2+Ter 2 out of 3 times and T2+Pum+Bli 1 out of 3 times.

5.5.1.3. Reflections on the equilibrium strategies

I have now performed game theoretic analyses on two games, one with perfect information and one with imperfect information. Remember that the goal of this chapter is to examine the role of information and based on that I will now shortly summarize the results of the previous analyses:

- In the game of perfect information the identified equilibriums originated in the two allied strategies Rif+Air and Rif+WSC+Air which were answered by the axis strategies T2+Ter and T3+Pum+Bli. The Rif+T4+Air is also a viable choice in the case that the axis player chooses T3+Pum+Bli.
- In the game of imperfect the identified mixed equilibrium included Rif+WSC+Air (1/3) and Rif+Ran (2/3) for the allied player and T2+Ter (2/3) and T3+Pum+Bli (1/3) for the axis player.

No matter if the information is imperfect or perfect the equilibrium strategies include only two strategies for the axis player, namely T2+Ter and T3+Pum+Bli. For the allied player it is quite different since four strategies are part of the equilibrium strategies of both games.

Looking at the payoffs of the two games the allied seems to be advantageous. In the game of perfect information the outcome is C,F which clearly favours the allied player. In the game of imperfect information the possible payoffs for the allied player are 2, 0, 1 or 2 and for the axis player they are 0, 2, 1 or 0 which again clearly favours the allied player.

It will be interesting to examine the game that includes elements of both the perfect and the imperfect game and see if situations will emerge where other strategies will come into play.

5.5.2. Theoretic: The influence of information

In this section I will examine the sequential-move game with focus on how information about the strategies changes the game. This will be done purely theoretically based on the game tree and in the next section (Feedback: The influence of information) I will include information from real life.

5.5.2.1. The game and subgames

To better be able to talk about the game I have shown the various subgames available in the game:

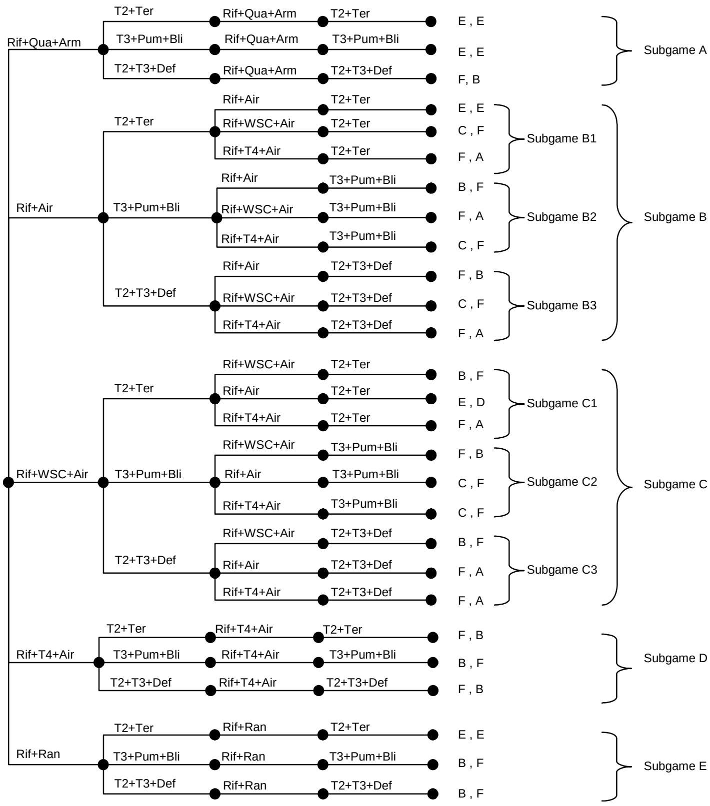

Figure 5.7: Sequential-move game with subgames[19]

A subgame is "Any set of nodes and branches descending uniquely from one node" (Ross, 2006) and are analyzable just like the complete game. In a subgame normally all players will be aware of the actions performed by the players before him, meaning that there is perfect information up until the beginning of the subgame. I will however mainly use the term subgame to speak of the various states the game could be in.

As seen in the figure above the subgames A, D and E involves only one choice while the subgames B and C involves two choices. I have furthermore chosen to let the two choice subgames consist of three other subgames (B1, B2, B3 or C1, C2, C3). The interesting difference between these two types of subgame is that the final decision maker changes.

[19] Imagine dotted lines between all choices (actually drawing these would mess up the overview of the figure)

5.5.2.2. Single choice subgames: A, D and E

In these subgames the possible payoffs are B, E and F for each player and how the payoffs are actually distributed is decided by a combination of the allied player's first decision (which results in the game to actually enter the subgame) and the axis player's first decision.

The axis player is looking for a situation where he knows that the allied player choose A, D or E before making his choice. If the allied player choose A or D he will be able to make a choice that strategically will give him the upper hand and if the allied player choose E he will be able to choose a strategy that will make the game strategically even.

The allied player on the other hand is also very interested in the choice performed by the other player. If the allied player gains information about the axis player's choice revealing that he has chosen T3+Pum+Bli or T2+T3+Def then he will able to gain the upper hand by choosing subgame E.

So in relation to the single choice subgames it is critical for both players to be the last to reveal their strategy as this would give them the upper hand strategically.

5.5.2.3. Dual choice subgames: B and C

In these subgames all the possible payoffs for the allied player are B, C, E and F while the payoffs available for the axis player are A, B, D, E and F. In relation to these subgames three choices are involved:

i. The allied player chooses between subgame B and C
ii. The axis player chooses between 1st, 2nd, or 3rd subgame within that subgame.
iii. The allied player gets another choice which results in the final payoff.

In the situation where the allied player knows the result of (ii) before making his first choice, then it is only rational to enter these dual choice subgames if the axis strategy is T2+Ter. If the allied player however is unsure about the opposing strategy then it would be rational to choose subgame C as this would, presuming that the axis player's strategy is revealed before making the last choice, result in a payoff of B, B or C.

In relation to the dual choice subgames the axis player has a structural disadvantage because on top of the even 'battle' of determining the subgame B1, B2, B3, C1, C2 or C3 (ii and iii) the allied player gets another choice where he will be able to make up for a potentially bad initial choice (iii).

Let us look into how the axis player might be able to make up for this disadvantage by tricking the other player into believing he is playing another strategy.

5.5.2.4. Signaling and commitment

The concept of signalling and commitment could be a way for the axis player to minimize the apparent structural advantage that the allied player has.

Unfortunately this 'extra' choice that the allies gain by selecting subgame B or C combined with the advantageous payoffs of choosing subgame E makes it impossible for the axis player to outsmart the allied player on a strategic level by the use of fake signals.

So was Company of Heroes (v. 1.7) badly balanced? Not necessarily. Remember how Channing pointed out that the Rif+Ran strategy (the one that leads to subgame E) was only successfully carried out by the elite players. He further mentioned that "I was like 40-2 with it and my brother was 63-3"[20] so for the top players it seems that the game indeed was balanced in favour of the allied side. But excluding the elite strategy and the picture is quite different.

With the allied side no longer having the more or less safe choice of subgame E (with payoff E, B or B) the concept of tricking the opposing side comes into play. Notice that removing this choice makes use of signalling more useable for both sides. Remember how the rational response for the axis player in a game of imperfect information was to choose T2+Ter 2 out of 3 times, which was the counter strategy to Rif+Ran. The fact that removing a strategic choice from one player affects the other is an excellent example of the strategic interdependence earlier mentioned.

Identifying credible signals

The useful signals that a player can make use of share two characteristics:

- Must put the opposing player in a situation where the decision he thinks is the best for him is actually the opposite
- Must be credible in order to make the opposing player believe the signal

I performed the examination of the sequential-move game with the purpose of identifying the possible signals with these characteristics in the back of my mind. This process revealed some quite surprising results.

I identified a total of nine signals that the axis player could make use that possessed the above mentioned characteristics. The surprise was however that only two signals were identified for the allied player. The reason for this seems to be because all but one signal will cause the axis player to choose T2+T3+Def. Only when the axis player believes that the allied player has begun the game using the Rif+WSC+Air strategy it is relevant for him to choose differently, namely the T3+Pum+Bli because it results in advantage for him – at least until the allied player changes strategy.

In the following table I have identified all theoretically legitimate actions in relation to sending out fake signals in order to force a response from the opposing side.

[20] 40-2 means 40 victories and 2 defeats

Axis	Signal	Real	Signal Choice	Real Choice
	T3+Pum+Bli	T2+Ter	D+2 (B,F)	D+1 (F,B)
	T3+Pum+Bli	T2+T3+Def	D+2 (B,F)	D+3 (F,B
	T2+T3+Def	T3+Pum+Bli	C3+1 (B,F)	C2+1 (F,B)
	T2+Ter	T3+Pum+Bli	C1+1 (B,F)	C2+1 (F,B)
	? + T2+Ter	T3+Pum+Bli	B1+2 (C,F)	B2+2 (F,A)
	? + T2+Ter	T3+Pum+Bli	C1+1 (B,F)	C2+1 (F,B)
	? + T3+Pum+Bli	T2+T3+Def	B2+1 (B,F)	B3+1 (F,B)
	? + T3+Pum+Bli	T2+T3+Def	C2+2/3 (C,F)	C3+2/3 (F,A)
	? + T2+T3+Def	T3+Pum+Bli	B3+2 (C,F)	B2+2 (F,A)
Allied				
	Rif+WSC+Air	Rif+Air	C+2 (F,B)	B+2 (B,F)
	Rif+WSC+Air	Rif+T4+Air	C+2 (F,B)	D+2 (B,F)

Figure 5.8: List of signalling possibilities

The table should be read as follows:

- Signal is the fake strategy signal that the player is sending out. A question mark indicates that the initial strategy should not be signalled; meaning that the first allied choice in these situations will be 100% uninformed.
- Real is the strategy that the player is actually playing
- Signal choice is the rational choice that the opposing player is making given that the signal is accepted (the payoffs are in brackets). The choice itself should be read as [subgame]+[choice in that subgame]. So B2+1 means choice number 1 in subgame B2.
- Real choice is the real choice the opposing player is making (the payoffs are in brackets)

Because the allied player in some cases has a second choice which is positioned relatively late in the game the usability of some of the strategies could be questioned. I will get back to this subject in the next section where behavioural information will also be included but for now let us instead take a look at how the signals relate to the structure of the sequential-move game.

The signals that cause the state of the game to enter the subgames A or D (single choice subgames) are easier to implement than the others. This is because the outcome of the game is already determined after two choices. This means that in theory the two first axis signals should be easier implementable and since they yield as good a payoff as any of the other signals, these signals theoretically would be preferable.

The two allied signals are however as easy to implement as the two first axis signals although they involve the subgame C which is a bit more complicated because of the three choices it includes. The reason for this is that the axis player's first choice also is his last, so from the allied player's perspective the subgame C is decided after two choices because the last choice is done 'automatically'.

5.5.3. Feedback: The influence of information

In this section I will examine the influence of information and signalling when actually playing Company of Heroes. This will be done based on feedback from the representatives I earlier presented (5.2.2).

5.5.3.1. Allied player: Fake signals

Earlier I only identified two possible signals that the allied player could make use of. From the player feedback I received it seems that no deliberate signals were send out in order to change the strategy of the opposing player. Wyatt Kopka points out how the initial Riflemen production could leave the axis player guessing because all the allied strategies started this way. When asked if the allied player would ever send out fake signals Channing replied:

> "Frankly no […] the US could adapt so well to anything that it will use its strategy up-front and to its advantage" (Appendix B)

So because the allied player could adapt well he apparently always put his confidence in the strength of his own strategy rather than trying to force the opposing player into making a bad strategic choice.

5.5.3.2. Axis player: Fake signals

Theoretically there were quite a few advantageous signals that the axis player could send out, but when it comes to how actually play the game it seems that very few of these signals are actually being sent out (I will discuss the reason for this in the discussion chapter). Channing however explains one way of sending out a fake signal:

> "Fake T2/Terror by getting veteran 1 infantry […] then pop out a puma or stuff as an armoured counter when they weren't expecting anything so heavily armoured" (Appendix B)

This signal makes use of the game mechanic that allows the axis player to deliberately apply veterancy[21] to his units (opposed to the allied player who gains this from combat). There was however also another way of sending out the same signal as General Grant describes:

> "One way is to go with a very heavy tier 1 build, which is manpower dependent but not fuel dependent, to suddenly spring out a Puma in the midgame to surprise the American player who has been dealing with Volksgrenadiers and MG42s alone the rest of the match" (Appendix B)

This signal relies more on the sheer amount of infantry and one could think that this signal would work well versus players of lower skill that might not be capable of picking up the signal regarding veterancy of the infantry units. On the other hand that signal seems a lot cheaper to send out. Steven Uray also mentions that going for heavy infantry and then switching to something heavier (he mentioned the flammenwerfer) was the most obvious signalling possibility that the axis player had.

---

[21] Veterancy means that the troops are more battle hardened and consequently tougher

The above signal was also identified theoretically but the feedback from the player representatives revealed another two signals that are not present in the sequential-move game. The first one is centred on faking a pioneer spam strategy (which I removed earlier due to its dominant features) and Channing describes it as:

> "My personal favourite was to go 3 pio start and send all 3 to one side, so people thought it was piospam and would be very cautious" (Appendix B)

This strategy obviously tried to make the opponent stall for a while possibly giving the axis player the advantage.

Wyatt Kopka mentions another way of sending out fake signals. It is however a bit complicated as it actually combines several of the strategies I depicted in the sequential-move game and therefore obviously is not present in that game. He explains:

> "Another way to hide a teching[22] choice was to pick the Blitzkrieg doctrine and use Stormtroopers as infantry, rather than building Grenadiers which reveal the presence of a Kriegs barracks.
>
> Stormtroopers could signal a fast tier 3, a tier 4 move, or a tier 2 build with Storms instead of Grenadiers. However, building tier 2 with Storms was the most surprising move since Stormtroopers usually signalled a fast tier 3 move" (Appendix B)

Building Stormtroopers early means that the allied player will not know if the axis player has built the T2-building. Furthermore the Stormtroopers can signal three strategies; fast tier 3 (T3+Pum+Bli), tier 4 (the one I excluded earlier, 8.3.6.1) or tier 2 (T2+Ter with Blitz instead of Terror). This means that Stormtroopers could be used a signal for a T3+Pum+Bli but actually be a variant of the T2+Ter strategy.

5.5.3.3. Summary of fake signals

I have summarized the identified signals that actually are being used in the following table:

[22] Teching refers to the process of improving the construction capacity

Allied	Signal	Real	Identified theoretically	Comment
	Riflemen	?	Not really a fake signal so no.	This signal is significant only in the fact that it holds no information because all allied strategies start with riflemen!
Axis				
	T2+Ter	T3+Pum+Bli	Yes	Two ways of sending this signal
	T3+Pum+Bli	T2+Bli (variant of T2+Ter)	Yes if we understand T2+Bli as a variant of T2+Ter	Interesting mixture of strategies
	Pio spam	?	No because Pio spam was removed due to its dominant features	Stalling the opponent by imitating Pio spam

Figure 5.9: Signals identified from analyzing feedback from player representatives

The most significant about the table is that the allied player has no real signals to send while the axis player's choices once again are centred on the T2+Ter and the T3+Pum+Bli strategies.

5.5.3.4. Adaptability and signalling

In the previous examination of signals (both theoretic and actual) the difference between the two playable sides has been significant. The allied player has more choices making him more adaptable while the axis player on the other hand have more choices when it comes to fake signalling. Looking back at my construction of the game of production capacity there are indications that the asymmetry identified there is actually the source of this difference.

Channing explains the difference between the sides and backs up the claim that it is the difference in production capacity that is the cause of this:

> "US almost always reacted to Axis strategy to be honest […] the Axis focuses on their strategy as they have a much more rigid tech structure. Linear teching means you have to know where you are going and when" (Appendix B)

This points us towards an understanding of the axis tech tree as being so rigid that the core strategy initially chosen will not be changed. This then forces the allied player into adapting to this strategy, which the game mechanics allow him to do. This indicates that the asymmetry in the production capacity impacts the two sides extensively and it might even urge different playing styles.

5.5.3.5. Importance of reading signals

We have seen that only a few signals are deliberately sent out, but there are of course also a lot of signals send out automatically. The obvious signals are units that reveal the construction of a specific building or the choice of a specific commander. Other signals are harder to read as they are much more subtle. Examples of these signals are here described by Channing:

> "the first sign of the Rif+quad will be the lack of rifle upgrades before the 8-10min mark" (Appendix B)
>
> "good players can work out that its T2/terror from the early zeal effect"[23] (Appendix B)

The first example shows that not upgrading your riflemen in fact signals that you are prioritizing your resources in a way that indicates that you are going for a specific strategy. In the second example Channing describes how good players can work out that the opponent has chosen a specific commander from his units increased ability.

He further points out the importance of reading these signals by stating that "if you can correctly predict your enemy then you can beat them easily". This statement is based on the assumption that the players are top players. The reason for this is described as follows:

> "top vs. top they know how to use everything and how to counter correctly etc. […] there will be minimal mistakes and no major ones" (Appendix B)

So what separates the top players is how good they are at reading signals and adapting and not their understanding of the game, as this is presumed to be at the highest level for all these players. Quite interestingly Channing continues the above quote stating:

> "…so the imbalances become more obvious" (Appendix B)

This indicates that the individual player's skill has an impact on whether the game seems balanced or not. Let us look closer into this subject.

5.5.3.6. Player competencies and game balance

According to Channing the imbalances become more obvious when the game is played out between two top players. This is an interesting point as it reflects what could be termed as a behavioural approach to the video game - taken to the extreme.

What I tried earlier with limited success was to group together elements of the game to form strategies purely based on the game's structure and rules. This behavioural approach instead looks at the strategies based on how a great number of people have actually played the game. Due to the complexity of most video games it is not entirely possible to come up with the perfect strategy based on the game itself and in connection to this it is interesting to examine how the 'best' strategy based on behavioural dynamics (via forums and chat rooms) change over time as better strategies are encountered. An

[23] Zeal is an ability gained from choosing terror company which boosts infantry temporarily

example that connects this subject to signalling and information is mentioned by Channing:

> "t2/terror was the mainstay axis strategy for sure […] t3+puma+blitz was the previous mainstay and so worked equally well and had some shock value when t2/terror took over" (Appendix B)

Here the community's (or the top player's at least) perception of the best strategy plays an active role in determining the opponent's most likely strategy. This actually means that a game that has been around for years can go from being balanced to totally unbalanced in a second. That second being where some player discovers a new dominant strategy and publishes it on the web. The pioneer spam was more or less an example of that. So balancing a multiplayer game that is played over the internet is most likely a process that will have to carry on also after publishing the game.

But luckily the balancing issues only apply to the mid level players on a much smaller scale. On the subject of player competency and game balance Channing mentions:

> "axis favoured at the higher levels for sure and the very lowest but mid-levels allies favoured" (Appendix B)

And in relation to this he concludes that "mid level would be more balanced I think (edit: than high level)". This is lucky for the game developers and the reason is found in the fact that the imbalanced strategies require much skill to even notice. Much in the same way that a custom made golf club might be the difference between winning a tournament and being the runner up, but for two average players it would not mean enough to even notice.

6. Discussion

Throughout the thesis I have touched various subjects in my work with game theory in connection to gameplay. This chapter will focus on the most interesting findings and discuss these in relation to my research question:

> How can game theory be used to analyze a strategic video game in relation to gameplay? - And what information does such an analysis provide?

The following figure shows the approach of this thesis in order to answer the research question:

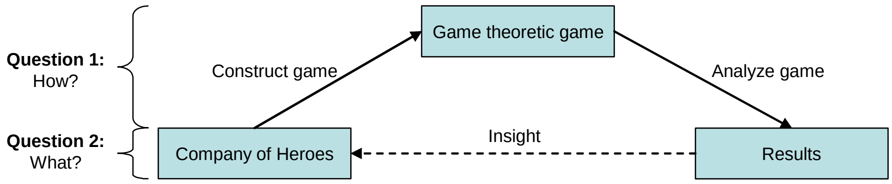

Figure 6.1: How the thesis answers the research question

The first question which relates to how game theory can be used to analyze a strategic video game will be discussed in section 6.1 and is centred on how the game theoretic game is constructed and analyzed.

The second question is about what information these analyses provide, which will be discussed in 6.2.

6.1. "How can game theory be used to analyze a strategic video game in relation to gameplay?"

This section of the discussion is structured as follows:

- First I will discuss my work with constructing game theoretic games based on Company of Heroes.
- Second I will discuss how analyzing a game theoretic game can reveal information about a strategic video game. The results of these analyses will however first be presented in section 6.2.

6.1.1. Constructing game theoretic games

In my work with constructing game theoretic games based purely on Company of Heroes I realized some fundamental problems (4.1.2). As a result of this I altered my approach which meant including information from Company of Heroes player representatives. In the following I will discuss the difference between the two approaches and reflect upon the consequences of my choice.

The first approach was purely based on the rules and environment of Company of Heroes and the aim was to reveal information about the gameplay. The second approach relied more on information about how the game is played. Three main problems with the first approach made me change the approach. In the following table I outline these problems:

Problems	First approach	Second approach
Payoff: Basic	Lack of strategic independence	None
Payoff: Representational	Hard to determine payoffs	Estimation
Choices: Representational	None	Simplification
Complexity	Incomprehensible size of game	Large but comprehensible

Figure 6.2: Problems in the construction of game theoretic games

So changing approach more or less eliminated the problems related to the lack of strategic independence and the incomprehensible size of the game theoretic game. It did however not remove the representational problems just alter their type. In addition to that it also introduced a new type of problem, the representational problem in relation to the choices. Let us have a look at these two kinds of problems.

The representational problems in relation to choices occur as a direct consequence of focusing on strategies in the video game. I examined this problem in (4.2.1) and the figure in that section illustrates the problem of this simplification process. When determining the choices that make up a strategy you effectively exclude all other choices, at least from a game theoretic point of view and this is the core of this problem. The goal of analyzing a game theoretic game based on pointers to strategies in the video game is to reveal information about the circumstances of these strategies, but what if the strategies do not correspond to how the game is actually played? In that case game theory will provide us with legitimate information, but unfortunately about a situation that has no foundation in the reality of the game which in our case means that the results are not usable. This is closely related to the other representational problem relating to the estimation of payoffs. Not only do the determined strategies have to be representative of the strategies people actually use, their internal weighting (payoffs) also has to be accurate. If either of these two is not depicting how the game is played it will influence the results of a game analysis, possibly rendering them useless.

So by changing the approach I eliminated the two problems that questioned the legitimacy of performing a game theoretic analysis. Instead two representational problems were introduced, although one of them was quite similar to a problem the first approach also had. This means that if those representational problems could be eliminated, then the results of the game theoretic analysis should in fact yield information about the strategic video game. Let us therefore take a look at the impact of these representational problems.

My approach of determining the various strategies was to retrieve information from various sources for then to compare these in order to establish strategies with good representational quality. I only accepted strategies that were proposed by at least two people. This meant that the strategies I chose most likely were good representations of strategies actually used in the game. On the other hand I excluded a number of strategies which might have resulted in an unnecessary simplification. I however prioritized being as sure as possible about the strategies I chose. Implications of the consequence of this are found in chapter (5.5.3.2) where a signalling possibility is tied to a strategy that I did not identify earlier. It is however a variant of one of the strategies I found but it shows how it is important that the strategies selected covers all the strategies used when playing the video game. This potentially conflicts with the approach of analyzing strategies as a simplification process is a fundamental part of the concept of strategies (in a video game perspective at least). Basically the first approach allowed us to create a game theoretic game that could depict all possible strategies in the video game. Unfortunately only theoretically, because constructing such a game theoretic game would in fact be impossible, much in the same way that it is impossible to do the same for a game of chess (Page). The second approach on the other hand only depicts few of the possible strategies but hopefully exactly the ones being used at the given time. This obviously includes a dynamic factor regarding the currently used strategies, as any given day some person could discover a new strategy that would be the new mainstay strategy (5.5.3.4). The discussion of how the representational problems in relation to determining the choices yield information on the two different approaches I have made use of. The first approach attempts to include all choices available in the game and is therefore not limited by any external factors such as the people playing the game. In a complex game as Company of Heroes this approach is however impossible to execute. The second approach attempts to analyze the game based on simplifications (strategies) which causes it to depend on an interpretation layer (in my case player representatives). The existence of this layer affects the results in such a way that there is a possibility that these are not automatically independent of external factors. Performing an analysis as I did at the very launch of Company of Heroes would more likely than not have yielded different results, because not many strategies were then 'known to the public'.

My approach of determining the payoffs related to the various strategies was quite different from actually identifying the strategies as I basically chose to base these values on the feedback from only one person. The reason for this is found in the nature of the two tasks. I used a group of people in the process of identifying the strategies because it was very important that the strategies were representational of how people played the game. In the case of determining the payoffs the most important factor is that the payoffs depict the game well. When determining the various strategies it was fine to receive feedback from players who mainly played either axis or allied as I combined the results. It is however quite different when the importance of the feedback lies in a comparison of the strategies which obviously calls for a greater insight into the game. Based on several factors I chose to let Channing handle this step single-handedly. These factors included several recommendations, his position at game replays and the quality of his feedback in relation to determining the strategies (Appendix B). I believe that I would not have gained significant quality or legitimacy by gathering feedback from more or other people but some kind of quantitative study could possibly have given me additional information. Examining a high number of replays comparing choice of strategy to who actually won the game could have backed up the claims by Channing. Besides the fact that such quantitative analyses would hold significant sources of error the main reason for me not to make use of such techniques was my choice of approach. As earlier mentioned the intention behind using representatives was for them to act as the interpretation layer that is defining my second approach. The general difference between performing extensive quantitative studies and my approach which more relies on qualitative feedback is the person who does the interpretating. Qualitative studies would make me interpretate the situations as opposed to the approach I chose where the representatives did the interpretations.

6.1.2. Analyzing game theoretic games

I will discuss the specific results from analyzing the game theoretic games in the next section and now instead focus more theoretically on what information such analyses can provide.

The game theoretic analyses in this thesis have naturally been centered on finding the equilibrium strategies. In relation to the game theoretic game in chapter (5.5.2.1) I additionally focused on the signalling opportunities. In the following I will discuss these two subjects with focus on how they can provide information about a strategic video game. Note that I in this section presume that the game theoretic games are depicting the strategic video games perfectly.

6.1.2.1. Equilibrium strategies and strategic video games

As mentioned earlier finding the equilibrium of a game means finding the solution. Nash proved the existence of a general equilibrium in all non-cooperative games:

> "Nash proved that all non-cooperative games have a Nash equilibrium, and thereby established an analytical structure within which all situations of conflict and cooperation could be studied" (Hallinan, 2005)

And Carmichael describes the equilibrium strategies as follows:

> "Game theorists focus on combinations of the players' strategies that can be characterized as equilibrium strategies. If the players choose their equilibrium strategies they are doing the best they can given the other players' choices. In these circumstances there is no incentive for any player to change their plan of action" (Carmichael, 2005, 6)

This means that if we identify the equilibrium strategies then we will have obtained important information about how the game is played. The information falls in two categories:

i. Which pure strategies are a part of the equilibrium strategies? and

ii. What are the possible payoffs?

This information is transferable to the strategic video game that the game theoretic game is depicting given that the players are rational and have complete information.

This effectively puts us in a situation where analyzing game theoretic games will be able to tell us something about the equivalent strategic video game played by players who want to win and who knows the game perfectly. I think it is fair to presume that these two characteristics are present in all top level players and obviously not in new or casual players. Let us now return to (i) and (ii) and examine the impact of these types of information.

From a design perspective it is quite interesting to discover what strategies are included in the equilibrium strategies (i). The reason for this is that all other strategies rationally would never be chosen which might indicate the need for rebalancing in order to include all or at least more strategies.

Examining the payoffs of the equilibrium strategies reveals information in relation to dominance. This shows the designer of a game if one of the sides is favored and in that case to which degree.

6.1.2.2. Game theoretic signalling and strategic video games

Signaling is a game theoretic concept that occurs in games with asymmetric information. The concept is centered on taking costly actions to reveal private information with the intention of affecting the choices of the opposing player.

Examining a game theoretic game for its signalling opportunities will reveal the credible signals that each player can make use of. The distribution of these opportunities could be interesting for a game designer as it reveals where in the game it makes sense to send out signals and where it does not.

6.2. "…And what information does such an analysis provide?"

In this section of the discussion I will look into the actual results of my work. I have chosen three key topics that cover my most interesting findings and I will discuss these one by one in the following.

The first topic is related to the direct results of performing the game theoretic analyses. The rest of the topics discuss my findings on a broader scale.

6.2.1. Results from a game theoretic analysis of Company of Heroes

In this section I will discuss the basic results of performing game theoretic analyses based on Company of Heroes. The results fall in two categories: Equilibrium strategies and signalling opportunities.

6.2.1.1. Equilibrium strategies

In chapter (5.5.1) I performed both the analysis of a simultaneous-move game and a sequential-move game. The reason for this was the fact that Company of Heroes is a real time strategy game, which means that all the choices can not be classified as either simultaneous or sequential. Remember that simultaneous/sequential choices correspond to uninformed/informed ones or in a game theoretic terminology a game of imperfect/perfect information. Although it was clear that neither a simultaneous-move game nor a sequential-move game would depict the game well I hoped that solving each of these extremities would make a good starting point in my analysis of Company of Heroes.

The equilibrium strategies for the two games were as follows:

	Imperfect information (simultaneous-move)	Perfect information (sequential-move)
Equilibrium strategy	Allied: Rif+WSC+Air (1/3 prob.) and Rif+Ran (2/3 prob.) Axis: T3+Pum+Bli (1/3 prob.) and T2+Ter (2/3 prob.)	Rif+Air + T2+Ter + Rif+WSC+Air or Rif+WSC+Air + T3+Pum+Bli + Rif + Air or Rif+WSC+Air + T3+Pum+Bli + Rif+T4+Air

Figure 6.3: The equilibrium strategies

This clearly showed two central strategies for the axis player (T2+Ter and T3+Pum+Bli) while it was quite different for the allied player who had four strategies that were part of the equilibrium strategies. My analyses furthermore showed a strategic advantage for the allied player (5.5.1.3).

Although not specifically representative of the real time gameplay in CoH the equilibrium strategy for the axis in the simultaneous-move game seems to fit the statement of Channing:

> "…most people thought with axis, I'll go t2/terror but as allied were expecting this and going strafing runs and BARs sometimes you'd see fast bars and think well I'll get a puma then" (Appendix B)

In his statement Channing however also highlights one of the main differences between the games of imperfect/perfect information and CoH. He mentions the word 'expect' and changing a strategy based on choices made by the other player. These two subjects are not both present in either of the above games. The game of imperfect information does not allow for any correspondence between the players before the choice is made while the nature of the game of perfect information renders both concepts useless (you will know the choice of the other player before making your choice, so why bother thinking about what he might do?).

On one hand the results of these analyses seem to hold information that is backed up by an insightful player of CoH. On the other hand the structural differences in the timing of the choices between these game theoretic games and the strategic video game that they are attempting to depict seem to limit their usability.

This leads us to the concept of signalling that might be able to help us close the cap between the simultaneous/sequential game theoretic games and the real time strategic video game.

6.2.1.2. Signaling opportunities

In the previous section I examined games of either imperfect or perfect information by examining a simultaneous-move game and a sequential-move game. This does however not mean that all sequential-move games are games of perfect information, although simultaneous-move games always are games of imperfect information. To better depict the choices in Company of Heroes I made use of a game theoretic game that could include both sequential and simultaneous choices. Ross speaks of this difference:

> "It was said above that the distinction between sequential-move and simultaneous-move games is not identical to the distinction between perfect-information and imperfect-information games. Explaining why this is so is a good way of establishing full understanding of both sets of concepts. As simultaneous-move games were characterized in the previous paragraph, it must be true that all simultaneous-move games are games of imperfect information. However, some games may contain mixes of sequential and simultaneous moves" (Ross, 2006)

The game Ross mentions in the last sentence corresponds to the 'sequential-move game with dotted lines' that I have used in this thesis. By simply attributing uncertainty to the choices in the sequential-move game I would still have the opportunity to depict a series of choices as opposed to the single-choice nature of the simultaneous-move game. This would further allow me to examine the role of this uncertainty as it introduced the concept of signalling.

My first move was to identify all the possible signals in the game theoretic game which resulted in nine possible signals for the axis player and two for the allied player (5.5.2.4). When I compared this with information gathered from the CoH representatives (5.5.3.3) only two signals were identified by both the game theoretic analysis and the representatives.

These two signals were tied to the two main axis strategies T2+Ter and T3+Pum+Bli while no signals were identified for the allied player. Although one of these signals could be transmitted in two different ways it is still very few of the rationally possible signals that are actually being used when playing the game, only 2 out of 11 (further discussion in 6.2.3).

It is however important to remember that these are signals that can be sent out deliberately to alter the strategic situation of the game. There are obviously also a lot of other signals that are being sent out more or less unknowingly. Channing pointed out the importance of reading these signals which is something I have only touched based on a structural understanding of the various choices (8.3). In relation to further work digging deeper into this concept of reading signals in relation to a strategic video game would be quite interesting.

In the following discussions I will take knowledge gained from my work with game theory and apply it to discussions on a more general level examining possible implications on interesting aspects of the concept of gameplay.

6.2.2. Implications of game mechanics

My initial approach of applying game theory to a strategic video game was to focus 100% on the game itself. Although I ended up using a slightly modified approach the focus on the core game mechanics and choice structures was not a complete waste of time. The process revealed some valuable information when the results of my final game theoretic analysis were clear.

When analyzing Company of Heroes in order to create the game of production capacity (8.3.6) I identified a difference in the structure of how the two sides gain the ability to produce better units. I also examined the commander selection mechanic (3.2.2.4).

At the time I did not expect that this slight difference in production capacity and the structure of commander selection would have such a vast affect on the game as I learned in chapter 5.

There was however an indication of the importance of the difference in the structure of the production capacity. Analyzing the game of production capacity revealed an interesting dynamic in relation to game balance which meant that the allied player had a slight strategic advantage from the beginning of the game until the moment where the axis player learned what initial building the allied player had built. At that point the axis player actually had the advantage. This apparent connection between information and game balance based on an asymmetry in the game mechanics seemed quite interesting.

A similar mechanic was apparent in relation to the commander selection but on a broader scale. In chapter 5 I eliminated a lot of strategic choices simply because the change of commander is not possible in Company of Heroes. The fact that choosing one commander eliminates a number of previously available strategies makes the choice very important. Not only for the player choosing the commander, but also for the other player. If one player for instance discovers that the other player has chosen a given commander, then he can perform an informed choice of commander, possibly giving him the advantage. The player who selected commander first may on the other hand have been able to benefit from the extra abilities effectively giving him the advantage until the choice is revealed by the other player. The consequences of this is that it is not possible to state whether it is best to choose commander first or last, exactly in the same manor as it is not possible to determine whether it is best to have the two initial choices as the allied player has or one as the axis player has. It all depends on how the game is played out.

So apparently interesting situations can occur as a result of a rigid choice structure, but how come? Maybe one answer lies in a quote I presented earlier in the thesis (3.2.3):

> "…a good game is one you win by doing something your opponent did not expect and making it work." (Rollings & Morris, 2004)

The quote is taken from a section in the book *Game Architecture and Design* about gameplay and it established a connection between winning the game and doing something your opponent did not expect. So maybe the reason why these irreversible choices of commander selection can result in interesting situations is found in connection to actually winning the game. This would point us towards an understanding of these choices as interesting because they actually have such an impact on the game that the signals surrounding these choices are worth exploiting.

6.2.3. Information: Signaling as part of core gameplay?

As discussed above there has to be an incentive to actually make use of signalling. If it is not worth it to exploit the signalling opportunities then the players of the game will naturally not include this in how they play. The other prerequisite for signalling to be a part of the gameplay is obviously that the signalling opportunity has to exist. The two requirements for signalling to be a part of a strategic video game are then:

i. Signalling possibilities must be present
ii. Signalling must be worth it

These requirements are obviously very basic, but as I identified 11 legitimate signals of which only 2 are actually in use (according to the CoH representatives) it seems that 9 of the theoretic signalling possibilities are not implemented in such a way that it holds both the above requirements. Let us take a look at how signals are a part of Company of Heroes.

From the feedback received about signals from the representatives it is clear that signals in CoH are very subtle and by no means part of the core game mechanics. As an example Channing explains the initial signals of two strategies:

> "The first sign of the Rif+quad will be the lack of rifle upgrades before the 8-10min mark and then the quad itself. The first sign of the rifle+air will be BARs upgrade very early around 6-8mins in" (Channing)

This shows what I mentioned earlier, that reading signals plays a greater part of CoH than actually sending out deliberate signals. This corresponds quite well with my description of understanding signals in a strategic video game based on the model of signal transmission (3.4.3). With CoH lacking real game mechanical signalling opportunities it is obvious that players prioritize reading signals over sending out fake signals. Could there however be other reasons for the lack of signals? One of the core concepts of game theory is strategic interdependence. The lack of this would be a plausible reason for why people do not bother sending out many fake signals as it relates closely to (ii) about the signal not being worth it. Let us take a look at this concept.

6.2.4. Strategic interdependence and signalling?

In connection to game theory Carmichael describes the concept of strategic independence:

> "Game theory is a technique used to analyse situations where for two or more individuals (or institutions) the outcome of an action by one of them depends not only on the particular action taken by that individual but also on the actions

> taken by other (or others). In these circumstances the plans or strategies of the individuals concerned will be dependent on expectations about what the others are doing. Thus individuals in these kinds of situations are not making decisions in isolation; instead their decision making is interdependently related. This is called strategic interdependence and such situations are commonly known as games of strategy" (Carmichael, 2005, 3)

Although described in relation to game theory the concept of strategic independence, like signalling, is not something unique to game theory. It is actually the opposite in the way that these are concepts observed in 'real life' and game theory offers a way of analyzing them.

In the above quote Carmichael states the following in relation to the existence of strategic interdependence:

i. In game theory the outcome of an action depends on the action of others
ii. In the circumstances of (i) the strategies will depend on expectations of what the others are doing
iii. (ii) is called strategic independence

This means that there has to be a connection between the actions of the players in relation to the specific outcome. If this is the case, then a chain of actions can be grouped together forming a strategy. The reasoning is then that if the building blocks of the strategies (the actions) were dependent of actions of others, then the strategies themselves must also be dependent of strategies of others which constitute the concept of strategic interdependence. This seems pretty fair and basically means that by examining the choice of actions in the game theoretic game I created (5.5.2.1), we will be able to discuss the concept of strategic interdependence.

When examining the game the presence of strategic interdependence is clear. None of the real choices are insignificant for the player not making the choice (different payoffs), which means the connection between the choices has been identified. This however comes as no surprise as this is common in games of pure conflict, which is what we are dealing with.

But what about the 'choices' where there is only one option? Because there is only one option these are not real choices, since both players knows the outcome of the 'choice'. This effectively rules out the prerequisite in (i). In relation to the strategic interdependence this is interesting because the consequence of this is that there is no uncertainty associated to these choices. With no uncertainty present the opposing player will not have to let his strategy depend on expectations because he knows that the opposing player in fact does not have a choice. This effectively shows the lack of strategic interdependence in connection to these 'choices'.

When examining the sequential-move game (5.5.2.1) it is seen that all of the axis player's second choices and approximately half of the allied player's second choices are of this kind. This means that once the axis player has chosen his initial strategy, then he does not change it and the allied player only changes his strategy in 50% of the cases.

I started the discussion of strategic interdependence in order to gain further knowledge in relation to the apparent lack of deliberate signalling in CoH. The results of this discussion indicate that there in fact is a lack of strategic interdependence, at least when we look beyond the first initial choice of both sides.

So the apparent lack of universal strategic independence seems to influence the usage of signals in a negative way. Three out of four of the choices after the initial choice are not real choices, which mean that there is a 75% risk that the investment associated with sending out a signal is wasted.

In connection to this Channing adds some insight:

> "The Axis focuses on their strategy as they have a much more rigid tech structure. Linear teching means you have to know where you are going and when"
>
> "The US could adapt so well to anything that it will use its strategy up-front and to its advantage"

This is actually quite interesting, as the two sides apparently have two completely different reasons for focusing on their own strategy. The axis player is forced into following his predetermined strategy because of a rigid tech structure while the allied player has so many opportunities of adapting to any strategy that he do not care if the opposition knows what he is playing. So we are dealing with two completely different playing styles based on the asymmetry of production capacity that I earlier discussed. There are however no fundamental reasons in the structure of the production capacity why signalling is used this little. Instead it seems that the reason for the lack of signalling in Company of Heroes is based in the lack of game mechanical signalling opportunities which then causes the signals to be too expensive and consequently not worth it in the end. By expensive I hereby mean the combination of the costs of a signal held up against the chances that this signal would actually be read by the opponent.

6.2.5. Summary of game mechanics, signals and strategic interdependence

My initial work with the choice structures of Company of Heroes revealed two main game mechanics that would affect the information structure of the game in relation to signalling and the strategic interdependence. In connection to this an interesting form of game balance was identified which was based on information more than on classical game mechanical attributes. These game mechanics were the asymmetry in production capacity and the choice of commander.

Based on a comparison of the results from a game theoretic analysis and the feedback from the CoH representatives I went on to examine the information flow in CoH by looking at signalling. Only two out of eleven possible signals were being used according to the representatives and I wanted to know why.

I identified two main reasons for why signals are not as big a part of the core gameplay of CoH as one might expect:

- There are no explicit game mechanics allowing signals to be send out. A consequence of this is that the signals in CoH are extremely subtle.
- A lack of strategic interdependence means that a high percentage of eventual signals would have no effect.

Combining these two points with the feedback from a CoH representative added further knowledge about the reasons behind the lack of signalling. A clear connection was made between the lack of deliberate signals and the structure of production capacity for each side. Indications of two different playing styles based on the structure of production capacity were revealed but both had incentives to primarily focus on their own ability over tricking the opposing player.

7. Conclusion

In this chapter I will sum up the results of this thesis by answering my research question:

> How can game theory be used to analyze a strategic video game in relation to gameplay? - And what information does such an analysis provide?

First sub question

Game theory can be used to analyze a strategic video game by performing two main tasks:

i. Construct a game theoretic game that depicts a strategic video game

ii. Analyze the constructed game

I initially attempted to directly map the choices in Company of Heroes onto a game theoretic game but that was not possible due to the extreme size of such a game. Therefore I had to reduce the size of the game theoretic game.

My first approach was to only depict a small part of the strategic video game, but the usability of analysing such a game theoretic game was very limited as it did not take into account all factors of playing the strategic video game.

My second approach was to primarily focus on the strategies in the strategic video game. This proved a lot more successful as I was able to depict the entire strategic video game and furthermore examine the relationships between the various strategies. This simplification however introduced some representational problems that I tried to minimize by incorporating information both from the game itself and from a group of Company of Heroes representatives.

When analyzing the constructed game the relation to gameplay is introduced. By finding the equilibrium strategies of the game theoretic games different types of information are revealed. Given that the players are rational the equilibrium strategies will tell what strategies are being used and more importantly what strategies are not. In addition to this it will produce information in relation to the balance of the game and the information/signalling structure of the game. These two subjects are important for the game designer in relation to designing the rules and environment which constitute the gameplay (as mentioned in chapter 1). Regarding the player I established a connection between strategies and gameplay in section 3.4.2.

Second sub question

Analyzing a strategic video game as described above will provide information of different types. In the specific case of analyzing Company of Heroes the most significant findings were in the following areas:

- Equilibrium strategies: Which strategies should each side choose?
- Balance: Which side is favoured based on the above?
- Information: The influence of signalling

By determining the equilibrium strategies I discovered that only two axis strategies and four allied strategies were a part of these. This gives an indication of which strategies might require an overhaul in relation to balancing. This is based on the reasoning that if a player theoretically should never choose a given strategy then the time spend developing the unique choices that relate to that strategy is wasted.

Based on the equilibrium strategies I identified that the allied player apparently had a slight advantage. The usability of this specific result is however questionable as I in the process excluded strategies that could have turned the picture around. But generally speaking there are implications that point us towards game theory as being a strong analytical method of determining the game balance. In addition information points towards the fact that the top players reveal a game's true balance and it seems that game theory is a viable way of analyzing this balance, mainly because this group of players are rational and have complete knowledge of the game.

The most interesting findings relate to information and signalling. Game theory offers a great framework for analyzing these subjects in relation to choice and I identified a clear connection between game mechanics and signalling.

By analyzing through the use of game theory I identified eleven signalling opportunities present in Company of Heroes. Through feedback from player representatives I learned that only two of these were actually being used. Based on knowledge gained from constructing various game theoretic games combined with feedback from players I identified the reasons for this lack of strategic signalling:

- The asymmetry in production capacity revealed two different playing styles: Allied with high strategic adaptability and axis with none. This resulted in a lack of strategic interdependence which consequently decreased the number of worthwhile signals. The reason for this was that the axis could not afford to change strategy while the strength of the allied was to adapt, effectively limiting the value of most signalling opportunities.
- The lack of signalling opportunities directly implemented in the game mechanics made the signals appear very subtle. The consequence of this could very well be that some signals would not be received as intended, consequently rendering signals less worthwhile.

The above points link the lack of strategic signalling directly to the game mechanics. This provides precise results that are relatively easy to use for a game designer. This highlights the strengths of using game theory to understand the gameplay associated with a deliberate exchange of information. By including game theory in my analyses I have been able to identify a rather precise relationship between the lack of signalling in Company of Heroes and some specific game mechanical features.

Summary

Based on the above a short answer to my research question would be:

Game theory can be used to analyze a strategic video game by analyzing a game theoretic game that represents the strategic video game and such an analysis can provide information about:

- The worthwhile strategies and how these are balanced
- The possible signals and their relationship with the game mechanic

8. Further work

Based on the knowledge gained from writing this thesis I think it would be interesting if someone would actually design a strategic video game based on the exchange of information and the concept of signalling. Poker seems to be very popular and the 'gameplay' of that game is basically based on those exact subjects, so why not try and apply this to a video game?

Additionally it would be interesting to perform a large quantitative analysis of how a specific strategic video game is played and analyze the information gathered based on game theory. Maybe the player's knowledge or information about the game could be analyzed based on game theory and the following reasoning: Every time a player performs an irrational choice, then remove information from the game theoretic game, so that his choice is actually the rationally best choice. The resulting game theoretic game would then depict the information or knowledge that this specific player holds?

Game theory offers an exciting way to understand video games and I hope that this approach will be applied to actual video game design sometime soon!

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10. Appendix A: Example analyses

In this chapter I will perform various game theoretic analyzes based on different situations from Company of Heroes. The overall goal of this chapter is to examine the gameplay choices in specific situations.

10.1. Method

I will construct several games (game theory) that represent specific situations in the video game Company of Heroes. In the following I will describe the key subjects in turning video game situations into game theoretic games.

Simultaneous-move or sequential-move?

As earlier described game theoretic games fall into two categories: Simultaneous-move and sequential-move. When mapping a situation from a video game into a game theoretic game it is important to determine which of the two game types that best describe the situation. In connection to this it is worth remembering that simultaneous moves are both true simultaneous moves but also sequential moves that are done hidden to the other player. So when deciding what game type to use in a given situation some understanding of the informational relations is required.

Choices

When the type of game has been determined the next logical step is to look at the choices. The simultaneous-move game is rather simple as it only includes one choice. This means that all options to each player are available.

Sequential-move games can include several choice-cycles which mean that the distribution of the options throughout these cycles is of critical importance. To create a sequential-move game that imitates a situation in a video game a thorough understanding of how the various choices relate to each other must be obtained.

Assigning payoff values

The hardest part of the process is however to get the payoff values right as they act as the link between the game theoretic and the video game theoretic understanding of the importance of the situations.

Assigning payoff values in an economic game is easy as it more likely than not will be an easy comparable type of payoff such as $ or £. Assigning payoffs to situations in a video game is completely different as it relies on an interpretation on the situations and their relation to each other.

The reason why the payoff values are the most important part of a game theoretic game is that the analyses of these games are based solely on these values. If the payoff values of a game do not represent the actual video game based value of the situations, then the complete analysis is worthless.

Assigning bad payoff values will therefore be the main source of error when applying game theory to other fields of study. In an attempt to minimize this source of error I will:

- Base as many of my payoff values on factual numbers from the game (Appendix B)
- Explain my reasoning thoroughly

10.2. Analysis: Selecting the gameplay choices

In this section I will select the gameplay choices that I will attempt to analyze through the use of game theory in the next section.

The analyses are essentially explorative as I try to uncover unknown information about the choices. This approach does however not ensure success, in the way that new information certainly will be found. To increase the chances of uncovering information I will attempt to apply game theory to a variety of gameplay choices. I am not just going to select a random number of gameplay choices and analyze them. Instead I will look at the structural difference between the general gameplay choices in Company of Heroes and select choices that represent each of the different kinds there are.

Levels of abstraction

So what differentiates the various gameplay choices in Company of Heroes (and other video games)? The level of abstraction.

As earlier described the gameplay framework was about the micro choices available in a video game and structurally all of these micro choices are similar. Whether it is building a bunker with an engineer unit, moving a rifleman squad behind some bushes or producing a tank it is all single micro choices. What is more interesting is that a number of these micro choices might constitute a choice on a higher level of abstraction. For instance all of the three micro choices just mentioned could be a part of one choice of a higher level, for instance the decision of mobilizing a defensive army. This choice could then again be a part of a choice of higher abstraction and so on. In the following table I present the four levels of choices that are available in Company of Heroes. These levels refer to types of situations in which specific kinds of choices are made.

	Description	Example
Micro level	Handling of specific troop units. Soldier-soldier combat and placement.	Driving a motorcycle unit in combat versus a machine gun unit. Dodging the machine guns arch of fire etc.
Low level (Meso level 1)	Capturing specific buildings/locations.	Assaulting enemy troops in order to capture a building or location (resource point etc)
High level (Meso level 2)	Securing strategically important areas of the map.	Securing a number of buildings, locations, bridges in order to cut off enemy units.
Macro level	Deciding overall strategy relating to unit types, commander type etc.	Choosing to go for armor as soon as possible in order to overwhelm the enemy midgame.

Figure 10.1: Categorization of levels in Company of Heroes

Notice how choices made on each level requires that a number of choices of lower level are made. An example of this is that capturing a specific location (low level) requires a lot of troop movement and so on (micro level) to be executed.

Based on the four levels of situations/choices I have selected the following situations as my initial subjects for game theoretic analysis.

- Game of units: Analysis of how units match up against each other
- Game of location: Analysis of the battle for a specific location
- Game of territory: Analysis of the battle for the various resource points in a map
- Game of production strategy: Analysis of production capacity

Notice how I have selected one game to represent each of the four choice levels. The game I have selected to describe the macro level gameplay choices is furthermore dependant on a few other games of lower abstraction, which I will also have to construct.

{If you compare the categories from the table with the games I earlier presented, then it is obvious that only the micro level and the low level have been covered. The game of units attempted to describe situations on the micro level, but failed because it did not take a number of factors into account such as map specific content. In the game of location I and II decisions on the low level were in focus. The real time aspect of the decisions in this context ultimately made these games fail in delivering a realistic outline of what happened in game. So at this point it seems that trying to understand the two lowest levels of situations in Company of Heroes through game theory is not possible. I will return to this discussion later in this chapter, but first let us try to focus on the two remaining levels of situations.}

10.3. Analysis: Creating the games

This section consists of a list of games (game theory) based on the situations that were selected in the previous chapter. For each game I will attempt to find its equilibrium (solution).

Game of units

This game is about the situation in which the players choose a unit to build. The goal is simply to examine what units beats what units. So let us have a look at the game in which the participants are not aware of what units the other participant is producing. Therefore the game is categorized as a simultaneous-move game and will be described using the normal form.

Assigning payoff values

In this game I have chosen to assign the payoff value of each unit as:

Payoff = PopCap Modifier X Weapon Rating(Infantry)

The reasoning behind this assignment function is that the weapon rating determines the damage done to the infantry type unit (which all the units in this game are). I multiply this damage by the PopCap modifier, which is how much population the unit expends. The PopCap modifier usually corresponds to the number of people in a unit. For instance the allied engineer unit has three engineers and the German pioneer unit only has two. Logically this results in 50% more damage done by the allied unit, which is also the result of the payoff based on the assignment function above.

Payoff matrix

	Grena-dier	Knight's Cross Holders	Machine Gun Squad	Mortar Squad	Officer	Pioneer	Sniper	Storm-Trooper Squad	Volks-grenadiers Squad
Airbone Infantry	10, 8	10, 18	10, 12	10, 9	10, 0	10, 2	10, 20	10, 8	10, 5
Engineer Squad	3, 8	3, 18	3, 12	3, 9	3, 0	3, 2	3, 20	3, 8	3, 5
Machine Gun	12, 8	12, 18	12, 12	12, 9	12, 0	12, 2	12, 20	12, 8	12, 5
Mortar Squad	9, 8	9, 18	9, 12	9, 9	9, 0	9, 2	9, 20	9, 8	9, 5
Ranger Squad	6, 8	6, 18	6, 12	6, 9	6, 0	6, 2	6, 20	6, 8	6, 5
Riflemen Squad	5, 8	5, 18	5, 12	5, 9	5, 0	5, 2	5, 20	5, 8	5, 5
Sniper	20, 8	20, 18	20, 12	20, 9	20, 0	20, 2	<u>20</u>, <u>20</u>	20, 8	20, 5

Figure 10.2: Allied vs. Axis infantry units: Normal form

As seen above this game has a dominant strategy, namely producing the sniper unit. This is very obvious and to be quite honest this game does not supply us with much useful information.

There are several reasons for this:

- The main reason is that the assigned payoffs all relate to the infantry-type unit. Since all the units in the game are of that unit type the choices made by one player does not affect the payoff of the other player.
- The payoffs assigned to each unit are only taking into account the sheer damage output the units are capable of delivering. This means that for a mortar unit this

means firing a mortal shell and hitting someone far away, while it for other units means up close combat. The usage of each unit in areas such as scouting, building etc is also not taken into account.

The above points indicate that the previously mentioned payoff assignment function is insufficient as it is not context specific. The main problem here is that it is more or less impossible to make this assignment context specific. The reason for this is that the payoff of the various units is made up of entirely different abilities. I do not believe that abilities such as invisibility, mobility, range and damage can be transformed into a numerical payoff value.

Game of location I

Moving a step up from the micro level choices this game is based on the opening situation in Company of Heroes on the map called Semois. The screenshot below shows the location this game theoretic game will be based on.

Figure 10.3: Screenshot of the context of our game

The points of interests are the church on the far left, the victory point in the middle and the building on the far right. The game is about the battle of this strategically important location.

Assigning payoff values

In this game I have assigned payoff values based on the context. While the goal obviously is capturing the victory point, the church and the building are also of critical importance. This game is constructed as a simultaneous-move game where both players decide whether to go for the church, the victory point or the building. The allied player starts closest to the church while the axis player starts closest to the building. So if both players choose the church, then the allied player will receive the largest payoff, as his troops enters the church and from there have better protection hence winning the fight. The opposite will happen if both players choose the building. If both players choose going directly for the victory point the allied player will also get the best payoff as allied engineer squads consist of three people opposed to the axis pioneer squads that only consist of two people. If one of the players choose to go for the victory point and the other player chooses to enter one of the building, then the player with his troops in a building will receive the largest payoff due to the increased damage he inflicts compared to his losses.

The axis player will receive an increased payoff if he enters the church while the allied player attempts to capture the victory point. The reason for this is that the church is better to occupy than the building (the structure has more hit points, and it is slightly better located strategically).

Payoff matrix

		Axis player			
		Church	Victory Point	Building	Other
Allied Player	Church	1, 0	1, 0	0, 0	0, 0
	Victory Point	0, 2	1, 0	0, 1	2, 0
	Building	0, 1	1, 0	0, 1	0, 0
	Other	0, 0	0, 2	0, 0	0, 0

Figure 10.4: Payoff matrix of the game of location

Using the technique used to determine whether a game has an iterated-dominance equilibrium (see section 2.4.1) it is easy to dismiss the choices "Other" as it for both players would be a bad decision (would only yield payoff 0). So now we are down to a 3 X 3 matrix. In this matrix choosing victory point for the axis player would now also only result in a payoff of 0, so we remove that choice as well. The axis player now only needs to decide between church and building. He will obviously choose church as this will give him a payoff of 0, 2 or 1 while selecting building would give him a payoff of 0, 1 or 1. With this knowledge the allied player has an easy time selecting church as well, as this is the only option available that would give him a positive payoff. So there we have it, this game I have constructed has an iterated-dominance equilibrium.

This seems fair since this game only takes into account one move by each player. This is of course not the case, so in the next game I will look at the battle for this location but based on a sequential-move game instead. As noted earlier this will also allow us to include more than one move in the game.

Game of location II

In the previous game the players made their choices simultaneously. This is obviously not a very fair representation of what is actually happening in the game – from the point where the opposing units meet. Before that point it is however a fair representation (remember how choices are not required to be made simultaneously for the game to be a simultaneous-move game, they just have to be made hidden from the other player). To improve the quality of the representation this game will attempt to map the situation in the video game from the point where the units meet.

Assigning payoff values

The process of assigning the payoff values in this game is very similar to that of the previous game. It is circumstantial interpretations based on the factual stats from the game (Appendix B).

Payoff tree

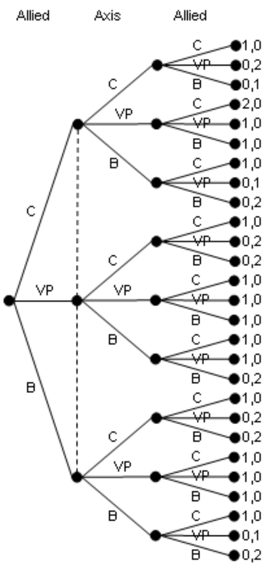

Figure 10.5: Payoff tree of the game of location II

This game is a sequential-move game that attempts to map the decisions available in a specific situation in Company of Heroes to a game theoretic game.

The dotted line means that at the time the axis player is making his choice he does not know what choice the allied player selected. Said in other words he is not aware of which branch the game is at. When the axis player has made a choice the allied player will observe this and gets the opportunity to react to it by making another choice. I will shortly describe an example of what could happen in this game:

The allied player chooses to move his troops to the church and the axis player moves his troops towards the building. The allied player observes the axis troops and decides to continue towards the church.

The two first choices are actually similar to those of the previously described game of location I, but the third choice differs as the player making the decision has information about what the opposing player chose. In the example above the allied player knows that the game is in the C-B branch, meaning that he will receive a payoff of 1 if he chooses to remain running towards the church. Changing course and going for the victory point or the building would have resulted in a payoff of zero.

In this game it is not really possible to speak about equilibrium. The reason for this is that all of the nine states the game could be in when the allied player makes his last choice hold an option that will yield a positive payoff for him and zero payoff to the axis player. This consequently means that the choice of the axis player does not matter as he will in fact receive a payoff of zero no matter what. Simply adding one more choice to the game would likely result in a game with the opposite situation, that the choices of the allied player would not matter.

Although the above game attempts to describe what happens in the video game in a more correct way it introduces some major flaws. I have summarized my points of criticism in the following:

- Describing these micro level decisions as a sequential-move game is not really doable. Notice how the payoff tree of game of location II only includes three choices. In reality the type of choices of that game are taken almost constantly. Imagine how often a player changes the movement of his troops and then think about all the times he decides not to change his troops that are already on the way. If you drew a payoff tree consisting of 10 choices per second, you could still argue that it would be better if the tree included 11 choices per second and so on.
- These micro level choices are not strategic and it is even questionable if they are tactical. Although the choices made are obviously dependant on the actions taken by the opposing player they are not strategic in the way that they are taken based on strategic considerations. They are merely operational choices made on the fly based on basic prerequisites. Much in the same way as you would choose to run away from an enemy with an AK47 in counter strike in the case that you were out of ammo.

Game of territory

Moving a step further up from the low level choices of the game of location this game takes its foundation in the entire map.

The game is based on a number of strategic points. Each of these points could be understood as the type of context I tried describing in the game of location II. While game of location II described how a specific point could be 'won' then this game is about deciding which points to go for and in what order.

The foundation of this game is the Company of Heroes two-player map called Semois. It holds 16 points that can be captured; 4 fuel points, 8 ammunition points and 4 strategic points. Below is a picture of the Semois map.

Figure 10.6: In game overview of the map: Semois

Based on the above screenshot I have made a diagram that more clearly describes the connections between the various points. For now I have chosen to exclude the victory points as their usage is not tied to any territorial status. Another reason is that this map is playable without the victory points as well.

I constructed a diagram to get a better understanding of the relationships between the various points. At first glance it looked like chaos, but after nudging the points around a bit I came up with the following diagram.

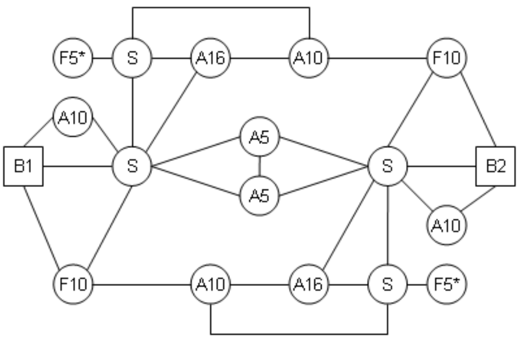

Figure 10.7: Resource and strategic point diagram: Semois (Company of Heroes map)

The map is exactly the same no matter what side you play, at least in relation to the resource and strategic points of the map.

Assigning payoff values

In this game it would be reasonable to assign the payoff values based on the numbers from the game indicating how much of the given resource the strategic points are giving. These numbers are both seen in the diagram above and the overview map presented earlier.

The payoff tree

I have decided not to draw a payoff tree for this game. There are three reasons for this:

- Drawing the payoff tree would quickly get out of hand. As an example take a look at the previous game and compare the relatively few choices of that game to the massive number of choices in this. It would not offer any valuable information because it would be too big to comprehend.
- The second reason why drawing a payoff tree would not offer any valuable information is that the resulting equilibrium would be based on choices mirrored choices. Image if the previous game (game of location II) offered no difference in the payoffs.
- The third reason relates to the fact that this game does not take into account other subjects than pure resource gathering. In connection to this (although basically contextually based) there are similarities to the first game presented (game of units). The main reason for this is that both games take into account only one or a few factors, consequently excluding other factors.

Game of overall strategy

This game reflects the macro level gameplay choices in Company of Heroes.

The goal of the game is to select the best overall strategy. To obtain any legitimacy in the construction of this game it is necessary to clearly describe the building blocks of this game.

The game has its foundation in the following four areas:

- Resource income
- Production capacity
- Upgrades (unit and buildings)
- Commander selection

Based on these four I will examine the process that happens in Company of Heroes when selecting the overall goals/objectives.

The area of application

Let us have a closer look at the application area of this game, namely the four areas mentioned above.

Resource income

Resources are needed to build units, upgrade units, use special abilities and so on. There are three types of resources: Manpower, Munitions and Fuel. In general manpower is used for building and for producing units (all kinds). Fuel is needed for building several important buildings and is also used when building tanks and vehicles. Munitions are used for weapon upgrades and for a variety of special moves.

Resource income will add to the construction of the overall strategy game through the following actions:

- Secure fuel points
- Secure munitions points
- Cut off enemy fuel supply
- Cut off enemy munitions supply

Production capacity

In order to field units a number of prerequisites need to be met. This is usually a question of building a number of buildings or upgrading the headquarters. Some buildings can be skipped in order to go more directly for some specific types of units (such as tanks for instance).

I will construct a game of production capacity in order to fully understand how and when the different sides can field what units. The payoff tree of this game will add to the construction of the overall strategy game.

Upgrades

Upgrades are type or unit specific alternations that are either pure improvements or tradeoffs. Some troop units can be equipped with anti-tank weapons and tanks can be upgraded with better guns or better armour etc.

Upgrades will add to the game of overall strategy in specific situations (game branches). With a few exceptions most upgrades do not seem to affect the gameplay choices on the macro level.

Commander selection

Through combat and resource gain the player is awarded with command points. These give access to a variety of abilities, ordered in three main categories. Only one of these categories can be chosen and under each category there are around 6 different abilities available hierarchically ordered in two lines. How this looks in game is seen in the image below.

Figure 10.8: Selecting commander abilities (Airborne commander in this case)

The commander selection will add to the game of overall strategy much in the same way as the upgrades, which means only when the specific situation makes the commander selection abilities critically important. The abilities gained through commander selections are however of much greater importance in regards to the macro level decisions than the upgrades are.

The connection between some of these areas is quite clear. Capturing fuel resources, building the structures needed to build tanks, upgrading your tanks and selecting the tank commander are all supporting the idea of tank warfare for instance. It is however vulnerable as it requires a lot of fuel, so if the enemy sees this and deliberately attempts to protect the fuel resources then it might prove a bad idea. Maybe it would be a good idea to also aim for some infantry support in the case that the above happens?

Game of production capacity

Let us have a look at the decisions regarding production capacity which in other words mean buildings. Different buildings allow the construction of different units.

In Company of Heroes the progress of production capacity is not a mirror image of each other (as we saw that the map Semois was). The allied side can build two buildings at the beginning of a game – barracks and weapon support center. The axis side begins the game with only one building option (regarding production capacity which is the buildings in focus right now). Both sides have a total of four buildings that can produce troops and in the following tree I have described all the choices that can lead to the construction of all four buildings for the allied side.

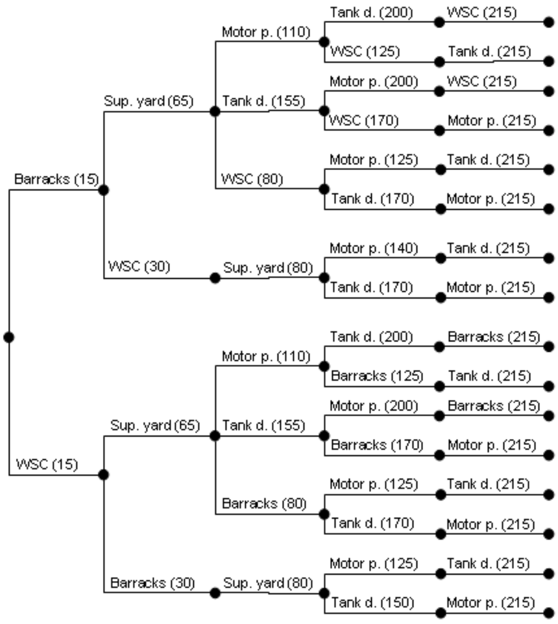

Figure 10.9: Tree describing the allied choice of building order

Building the supply yard will give the allied player the ability to build both motor pool (tier 3) and tank depot (tier 4). Notice that building either barracks or weapons support center is a prerequisite for building the supply yard.

The next diagram describes the choices that can lead to the production of all axis buildings that allows troop production, but with one exception. Due to the axis build structure a player could in theory gain access to building all buildings before actually building one. This would make the diagram extremely big and complicated, so I have decided to assume that all players begin the game by building the wehrmacht quarters. Since there is really no other option for the axis player at this point I believe this assumption to be legitimate.

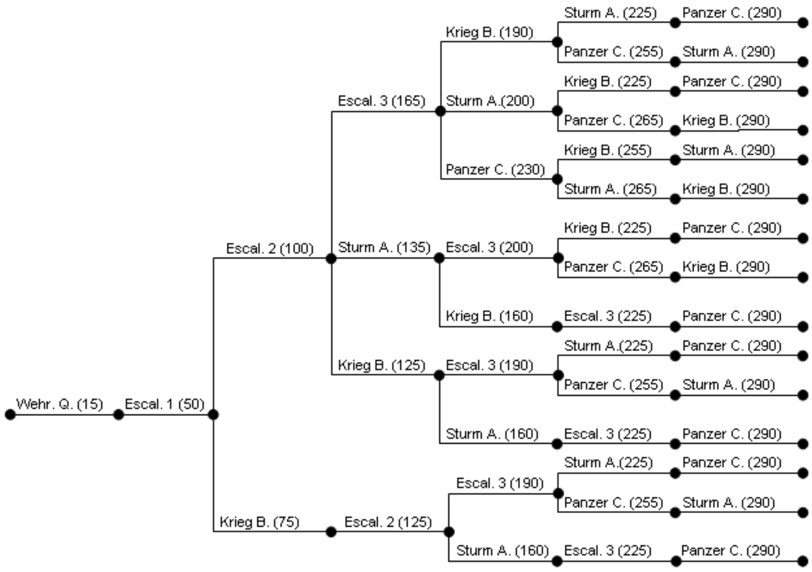

Figure 10.10: Tree describing the axis choice of building order

As seen in the diagram the axis needs to perform something called "escalate battlefase" to be able to build the next building in line. So to be able to build the panzer command (tier 4) the player must escalate to battlefase 1, then 2, then 3. Notice how this structure does not require the actual production of the tier 2 or tier 3 buildings before building the tier 4 one.

Constructing the game tree

The idea behind the construction of this game tree is combining the two above trees into a sequential-move game tree. Simply combining these would result in a huge tree that would not offer much insight into anything. Instead I have chosen to simplify the tree by removing improbable choices, quite similar to how I earlier removed the choice for the axis side to not instantly build the wehrmacht quarters. Most significantly have I removed the choice for the axis to go directly to the panzer command building (tier 4). I have also removed the choices for the allies to first build barracks and then WSC and vice versa. I will get back to this decision later in this section. Let us now have a look at the game tree I have constructed.

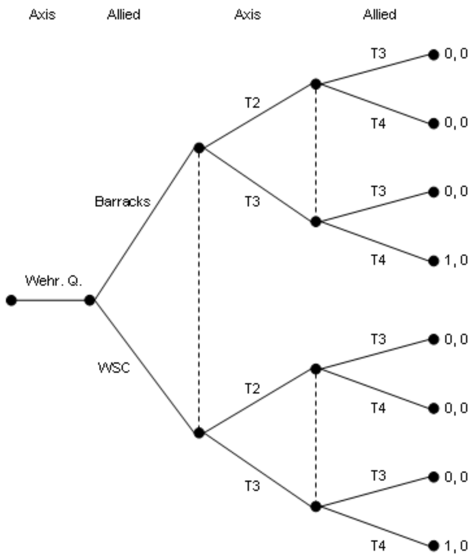

Figure 10.11:

The tree describes the first two moves in Company of Heroes regarding production capacity. I have only associated a payoff advantage to one side in two of the eight possible outcomes. The reason for this is that the success of the remaining six outcomes heavily relies on situational facts that obviously are outside this games context. Notice again how the dotted lines indicate that this choice is unknown to the opposing side.

Once again it is not of much use to talk about the equilibrium of this game since the choice of the axis does not matter as all his possible payoffs are zero. The reason for this is not surprisingly that the payoffs have not been determined. Although the game lacks the payoffs it is actually able to tell us something useful. In a sequential-move game the mere structure of the game holds valuable information. Reading the sequential-move game tree yields two legitimate questions that I will discuss in the following.

- "After one choice from both players the axis player will not know what building the enemy has built while the allied player will. Imbalance?"

  This is an interesting point as it involves both the basic game mechanics and the information the players have about each other. Game mechanics in the way that the allies have two buildings available from the start and the axis only one. Information is obviously important because this is what the statement is all about – knowing what building the opponent has built. This is where the above tree might fall short as the dotted line indicates that the axis player is making an uninformed choice when selecting either to built the tier 2 or tier 3 building. This is however not always the case as units from either the barracks or the WSC will roam the field before the axis player is capable of building the second building. So in some cases the axis player will in fact know whether the allied player has built barracks or WSC and sometimes he will not. If the axis player stumbles upon a group of rifleman early in the game, then the initial structural advantage the allied had will suddenly be gone and may even be on the axis side at this point in the game. So I would not judge this as an imbalance, and if I would, it would certainly not be in favor of the allies, although it might seem they are better off with two choices initially.

- "This game looks more as a simultaneous-move game than a sequential-move one!"

  This statement obviously has its foundation in the dotted lines in the tree, which are also one of the most interesting subjects in this game. Remember how sequential moves performed without the knowledge of the other are per definition simultaneous. The interesting fact here is however that these choices are not always simultaneous and not always sequential. This means that when the players decide to built a building they will sometime be informed about the opponent and sometimes not. Being informed is always at least as good as not being informed and in many cases it is better. This means that the players in some cases might want to search for information that will inform their choices consequently netting them a higher payoff than if they just guessed. This is really one of the core aspects in games of asymmetric information.

11. Appendix B: Documentation

The following Excel files are available on the attached CD:

1. CoH – Strategies.xls
2. CoH – Choice Analysis.xls
3. CoH – Unit Stats.xls
4. CoH – Fake Signals.xls

The interaction with the representatives is also available on the attached CD. The following list produces an overview of the files, which are confidential:

- Feedback – 12azor.doc
- Feedback – Surprise.doc
- Feedback – Bonedog.doc
- Feedback – General Grant.doc
- Feedback – RabidRacoon.doc