Modelling Group Dynamics with SYMLOG and Snowdrift for Intelligent Classroom Environment

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A thesis submitted for the degree of

Doctor of Philosophy

Department of Computer Science and Electronic Engineering

University of Essex

July 2021

Acknowledgements

I would firstly like to thank my supervisors Dr Michael Gardner, Professor Victor Callaghan, and Dr Jon Chamberlain. Dr Gardner was my main supervisor for the first 3 1/2 years of my PhD and greatly assisted me in crystallising my ideas and Professor Victor Callaghan was 2nd supervisor for my 1st year. Dr Jon Chamberlain over saw my write up period and on my supervisory panel either as a member or chair for the 3 years before. I would also like to thank Dr Alba Garcia Seco De Herrera for her support throughout my PhD.

I would also like to thank my mum and dad, Annette Longford and Colin Hoste for everything they have done for me during this long process. Finally I would like to thank my partner, Beyza Ucar, and all the friends I have not had enough time for over the past 4 years for being so understanding.

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Abstract

The aim of this thesis is to provide assistance to human teachers focusing on supporting group work within a classroom environment. This is achieved by incorporating theories from Psychology and Game Theory in order to provide a better method of modelling and predicting group interactions. This research proposes a framework that extends the pre-existing Intelligent Tutorial System (ITS) beyond the individual and into one that encompasses one or more groups of learners within a learning space. This framework transforms a traditional school classroom into a group interface as part of the communication module of an ITS and enhances the role of a human teacher. This is achieved by automating class management tasks and providing an immersive learning experience. Moreover, the proposed framework monitors emotional well-being and feeds back, to the teacher, emotional profiles of individuals and groups. This new ITS system is named Intelligent Classroom Tutoring System (ICTS). 6 experiments were conducted to support the ICTS. 2 experiments were set up to compare experimental frameworks for SYMLOG allowing the researchers to test a new mod-SYMLOG which was found to be an effective tool for modelling groups interactions. 1 experiment was centred around a longitudinal study of group work, and the final 3 composing of both AI and human studies, examining applying a new mod-Snowdift game to produce a predictive mechanism for group interaction.

Key Words

Group-Based Intelligent Tutoring Systems; Augmented Environments; Teacher-Centric Immersive Learning; Emotional Monitoring; Dynamic Lighting

Chapter 1

Introduction

1.1 Outlining The Problem

In England and Wales the number of students per class is increasing[28] while teacher recruitment is falling behind the Government's Teacher Supply model leading to a growing problem in student to teacher ratios in Secondary Education[43]. This problem of ratios in turn leads to increasing difficulty for any individual teacher to effectively manage classrooms[88]. The more students a teacher teaches, the greater the difficulty the teacher has in managing the classroom, and classroom management is essential to promoting good learning outcomes for students[34]. Is it possible to empower the teacher by allowing them to augment the learning spaces, to improve management of learners and thereby enhance the learners' experience and their academic performance?

1.2 Defining The Scope Of The Solution

This research investigates constructing a new model of group learning within a classroom environment. Firstly it is necessary to define the phrase "built environments as immersive learning spaces." Starting with the simpler elements, this research's concept of learning spaces are that of a classroom or lecture theatre, i.e. the spaces in which most children and young adults are introduced to academic learning via schools and universities. Built environments are the surroundings or conditions in which users are operating. The keyword within this phrase is immersive. Immersive environments, or Immersion in an environment has been defined by Slater as the extent to which that technology delivers 4 measurable dimensions in which a human user is immersed within the environment[107]:

1. Inclusive is how complete the user is isolated from the external world.
2. Extensive encompasses the range of mediums and external stimuli which are used to immerse the users, e.g. the stimulation of visual, auditory, and somatosensory receptors of the user.
3. Surroundings is how extensive or limited the range of inputs are, e.g. if the field of visual input is narrow or panoramic.
4. Vivid is the quality of the augmentation or virtualization of the constructed reality.

The theoretical framework for this immersive learning space framework attempts to extend the Intelligent Tutoring System (ITS) from the recognisable individual ITS systems towards a holistic and dynamic group-based system, seeking to bridge the gap between the advantages these systems have brought to isolated learners and the mass education system with human teachers instructing and assisting the academic development of younger generations. ITS is defined by Wenger as computer programs that use several technological resources to support a teaching-learning process[129]. This ITS model is, traditionally, divided into 4 component models: domain, student, teaching, and learning environment or user interface[44]. One of the main functions of any ITS is the adaptation of the system in response to the needs of the student/learner[70]. The Intelligent Classroom Tutoring System (ICTS) adds a Group Model to monitor the creation and interactions between group members, a Group Pedagogy Module to mediate the transmission of knowledge to the learner, a group user interface from which the group of students interact with the system. These components are connected to a human teacher, named the First Teacher, via a Teacher Interface Module. The human teacher is supported by 2 AI teachers, named the Second and Third Teacher, which interact with individuals and the group respectfully. See Section 3.1.3 for more details.

1.3 Research Questions By Chapter

This research seeks to develop a group based intelligent tutoring framework to support teachers within the classroom. To develop this, experimental work was designed and broken down into sections to explore areas of the research. Chapter 4 examines the creation of the Group Model as part of the ICTS. Chapter 5 attempted to test mod-SYMLOG part of the Group Model and its abilities to understand groups and predict group performance. Chapter 6 uses mod-SYMLOG to simulate groups, testing to determine when people withdraw from group interactions and test visualisations of groups developed in Chapter 4.

1.3.1 Chapter 4

1. Can either Europa Universalis 4 or Diplomacy be used in order to test modified-SYMLOG (mod-SYMLOG)?

2. Can mod-SYMLOG capture the interactions between groups?

3. Can mod-SYMLOG capture the formation of sub-groups?

1.3.2 Chapter 5

1. Can mod-SYMLOG be used to track groups long term?

2. Are mod-SYMLOG diagrams (SFD, 3D-SFD, and node diagrams) useful to group supervisors to monitor groups?

3. Can mod-SYMLOG diagrams be used to predict grades?

4. Can mod-SYMLOG diagrams be used to predict group breakdown?

1.3.3 Chapter 6

1. Which Prisoner's Dilemma strategy achieves the highest score in a game of modified Snowdrift?

2. After how many turns do players stop engaging with Snowdrift strategies?

3. Does using the mod-SYMLOG node diagram allow more accurate ratings of group cooperation compared with only analysing final game scores?

4. Can players accurately assess total contribution of groups from mod-SYMLOG node diagrams alone?

1.4 Contributions

A summary of contributions within this thesis.

1. Extension of ITS Framework to a group based ICTS Framework.

   The first contribution to the field of Computer Supported Learning systems is the extension of the ITS Framework from a single student interacting with a computer to looking at how a group would interact with multiple computers and/or an intelligent room and how those systems could interact with the students as both a group and as individuals.

2. Modification to SYMLOG

   The second contribution is modifying the SYMLOG input parameters from an adjective based system to a triple axis system. This system scores interactions by rating them independently by Dominance, Positivity, and Goal Orientation proving a methodology of rating group interaction and allow for conversion into Game Theory models.

   Mod-SYMLOG is also part of the Group Model component of the ICTS.

3. New method of representing SYMLOG

   The third contribution is representing SYMLOG relationships through a node diagram. This allows for a simple method to interpret group behaviour for those overseeing groups, e.g. a teacher and their students.

4. Modification to Snowdrift

   The fourth contribution is the extension of the Snowdrift game from Game Theory. This is a change from a binary Cooperate/Defect action to include light versions of action inline with different levels of contribution from both SYMLOG and mod-SYMLOG. This also builds a model for prediction of group behaviour and group breakdown to allow for interventions to take place.

1.5 Submissions

1.5.1 Published

Material from Chapter 3 published in:

Longford, E., Gardner, M., Callaghan V. Social Organisation and Cooperative Learning: Identification and Categorisation of Groups and Sub-Groups in Non-Cooperative Games. In International Conference on Immersive Learning 2019, 131-143.

Phase 2 experiments from Chapter 4 published in:

Longford, E., Gardner, M., Callaghan V. Group immersion in classrooms: a framework for an intelligent group-based tutoring system of multiple learners. In Workshop, Long and Short Paper, and Poster Proceedings from the Fourth Immersive Learning Research Network Conference (iLRN 2018 Montana) 133-135,

Walton-Rivers, J., Longford, E., Gomme, D., Bartle, R., Gardner, M. Distributed Social Multi-Agent Negotiation Framework For Incomplete Inform-

ation Games. In 2019 11th Computer Science and Electronic Engineering (CEEC)), 65-68.

1.5.2 Under Submission

Chapter 4 Phase 1 and Phase 2 experiments under submission in Computers and Education.

Chapter 7 under submission in User Modeling and User-Adapted Interaction.

Section 3.1.10 provides an example of using a database for teaching students about Women in STEM, which is under submission in Educational Researcher.

Chapter 2

Literature Review

2.1 Introduction

An individual's behaviour changes when they are part of a group[56], a group being social interactions between two or more individuals who share a common social identity[55]. These changes when within a group can depend on the size or where the focus of group members or external observers is. For example there is the Hawthorne effect, where behavioural changes are caused by an individual's knowledge of being watched by others, for example the increased use of antiseptic hand rub by members of an intensive care units[32]. Group behaviour can also lead to Deindividualisation, where group members become distant from their own personal identities, thus decreasing their need for social evaluation, and thus be more willing to break personal or social norms[94]. These behavioural changes happen in all group meetings, to a greater or lesser extent, and thus should be considered when creating group learning exercises. Goodman et al (2016) in their review paper of Computer Supported Collaborative Learning (CSCL) research conducted since their original paper in 1998, posed 6 open research questions resulting from perceived gaps in the literature. The 3rd question on their list was "Modeling of users takes on a different perspective in an intelligent CSCL. There are attributes of individual students (a 'student model') and of the whole group of human learners (a 'group model') that need to be tracked to best drive the instructional support"[50]. The view that groups exist, and that groups are under-examined within computer science research is supported by Stahl, he states "[...]it is proposed that CSCL research should focus on the analysis of group processes and practices, and that the analysis at this level should be considered foundational for LS[Learning Systems]"[113].

2.2 Psychology - An Introduction To Social Theories

Part of CSCL research within this thesis will focus on the creation of a group model, mapping the interactions of members of a group using theories from social psychology. Psychologists within social psychology do not need to belong exclusively to one school, and often may incorporate ideas and theories from other schools of thought, for example some social psychologists will use biological reactions within the brain (neurology) to assist in understanding social metaphysical interactions. This section shall review social psychology theories and experimental data. This will be followed in later sections by a review of educational and developmental psychology research, before introducing SYMLOG (SYstematic Multiple Level Observation of Groups) which will be used as the basis of the group model developed within this thesis.

2.2.1 Social

Social psychology is the study of how the behaviour, through processes and emotions of an individual are influenced by the presence of others. The presence of others can be real or imagined[15], as social psychology can be internalised, by the affected individuals even if they are alone. Social groups are identified by sharing commonly agreed norms, roles, and relations of members within a group[42]. Norms are a series of rules, often implicit, which members are expected to follow. Norms tend to be produced through 3 stages[40]:

1. Emergence - where a single or multiple norms are introduced to a group by one or more group members (entrepreneurs/originators).

    – The success of these new norms are often related to the perceived legitimacy or social power of the individuals introducing them (originators).

2. Cascade - where a norm takes acceptance among group members outside of the originators. Eventually these new norms will either reach a

a critical point, becoming accepted within the group, or rejected. Some factors that increase the probability of a successful cascade include:

- The legitimacy of the originators and other adaptors, and if those members adopting the new norm are rewarded (e.g. through additional social status).
- How similar the norm is to preexisting norms, the closer to similarity the more likely the uptake among members.
- The universality, i.e. their applicability to all group members.
- External events that might cause existing norms to conflict with new experiences. e.g. wars and pandemics.

3. Internalisation - where norms become fully accepted within a group, becoming a default pattern of behaviour. e.g. shaking hands, and offering food and drink to guests.

Roles are socially defined positions within a group. While most roles will adhere to the social norms of the group some will come with modifications which define interaction between group members with different roles. These are the relations between roles[42]. One example of roles and relations is that of student and teacher. The role of the teacher is not only to provide formal education, but also instruct the student about the social norms of the group in which both the teacher and students exist[11][48]. In some contexts teachers also provide pastoral care for both physical and psychological needs of the student[14]. The one requirement for the teacher's role to be successful is the balance of authority and trust between the teacher and student[46]. The student must see the teacher as an authoritative source of knowledge in order for the relationship to remain stable. The exact dynamics of this relationship will change over time depending on the type of lesson structure[98] (see Chapter 2.3 for more details), and the developmental level of the student (e.g.Piaget or Kegan for more details see Chapter 2.4)[69].

Justification theory is a social psychology model where behaviours or concepts are given legitimacy, existing either implicitly or explicitly within several social psychology theories[66]. Jost and Banaji (1994) identify 3 sub types of identification theory, ego-justification, group-justification, and systems-justification. Ego-justification focuses validating behaviours and beliefs on an individual level by projecting perceived personal failings upon others[23]. Little empirical evidence exists for this level of outward projection [23][66], but there is some evidence for its use as a self-defensive mechanism[23]. Group-justification is a theory of stereotyping at the group level, identifying both the self and other individuals as either members of an "in-group" or "out-group", then assigning positive attributes to members of the in-group (including themselves), and negative attributes to members of the out-group. Experiments have also shown hierarchies to exist within groups, not only as social status of individuals, but have also shown that in-group members with "lower" social status are more likely to have more favourable views of out-group members than members of their own in-group with "higher" social status are of the same out-group members[66].

One method to analyse the amount of time taken for groups to form is Social Identify Theory. Social Identity Theory attempts to explain inter-group conflict, based on the perceived legitimacy, status differential and mobility of members between two groups[2]. These interactions can be understood as discrimination, or preferential treatment of in-group members over out-group members. If this is all that is needed for a group to form at the most minimal level for this discrimination to take place then it can happen based on a coin flip. In one study by Tajfel, a group of boys were shown paintings by 2 "foreign" artists without any identifying marks on the paintings. They boys were then divided into two groups at random but were informed that they had been assigned based on preference for a particular artist. This assignment was enough for the subjects to maximise "profits" for their own in-group members over out-group members in a series of tasks following this group assignment[118]. While a small study, Tajfel's work still influences modern Social Psychologists[112].

Groups have been shown to be more "intelligent" than any individual involved within the group. This "collective intelligence" was defined by Woolley et al. as the group's ability to perform at various tasks (this is how individual intelligence is defined by Woolley and extended to the group). Factors such as individual maximum intelligence and average intelligence of individuals did not correlate strongly with the performance of the group. Perhaps surprisingly, group cohesion, motivation and satisfaction were also not strongly correlated with the performance of the group; however, when correlated against Group Intelligence, then these factors became a strong predictor of outcomes. There was also a correlation between collective intelligence and the proportion of women within a group, with the greater the ratio of women to men (i.e. more women) leading to higher scores for collective intelligence[130]. Similar results were found by Engel when examining online groups showing that group interaction causes an increase in group results in virtual environments[35].

Olsen examined the effects of collaborative methods that had been used on students in secondary and primary education. They compared students who collaborated with those who were given individualised work and found that, while the educational attainment did not differ between the collaborators and the individualisers, those doing collaborative group work completed fewer questions than individuals[90]. This is an indication that group work is not always superior to individual work.

It is also possible to use quantitative measures when examining group interactions. Jahng examined organising groups by using three measures, quantity (of communication), equality (of partnership within the group) and shareness (the team spirit). The quantity was measured by the number of words exchanged between group members. Equality was measured by how evenly the words were distributed among group members. Shareness is measured by how many members were included in each communication, one-to-all communication scored high and one-to-one scored low. The results were then scored on if the members continued communicating between each other after the activity had been completed. Groups with high scores in all three categories tended to continue to socialise/communicate after the contact period studied. Suggesting that these quantitative measures can be use as proxy of a qualitative analysis of group interactions[63].

2.2.2 Neurology

There is a physical change within the human brain that shows different mental states when an individual is in a group, which is more than just independent thought patterns. Some evidence that group interaction exhibits reciprocal effects is found when monitoring, bird[39], human[115] and monkey[97] brains using fMRI scanners. When watching a video an action, similar neurons within a viewing monkey's brain are activated as with the monkey performing said action[97]. These neurons are known as "mirror neurons", which are neurons that are activated both when an individual performs an action and when that same individual observes the same or similar action being performed by another individual[72]. It appears that most social animals have the ability to utilise mirror neurons, which are important for social-cognitive interaction (i.e. group formation and continuation)[39]. These mirror neurons have also been shown to synchronise neuron activity between a speaker and a listener(also known as "speaker–listener coupling"). Moreover, the level of neuron synchronisation can predict a listener's comprehension of a given speakers topic. The study by Stephens et al also shows a potential biological reaction to what psychologist and sociologist would refer to as group cohesion, as higher levels of synchronisation corresponded with a better understanding of the information being conveyed by the speaker. To support this hypothesis in part of the experiment one of the speakers spoke Russian to a listener with no understanding of Russian. It was found that the listener had significantly lower levels of both synchronicity and activity than when coupled with someone who spoke the same language[115].

Social psychology provides a powerful framework to analyse and understand group structure and a combination of behavioural and social psychology will be used within this research. From behavioural psychology SYMLOG (see Section 2.7) was selected and modified by the researchers and named mod-SYMLOG as the data collection framework (see Section 3.2), and techniques from social psychology are used to understand the structures of groups found from mod-SYMLOG.

2.2.3 Understanding The group And Its Importance To Learning And Development

Educational researchers have tended to agree that group learning has advantages over individual learning, with some researchers finding increased academic performance[16][53][131] and improvement in social skills[53]. However this does come with a caveat, the individuals reaction to working within a group. Studies from educational psychology have shown when group based learning was viewed as a positive event it tended to lead to greater socio-emotional skills in forming personal relationship, improved relationship with learning, and improved academic outcome[5][16][22][53][111][131].

Unfortunately, other studies[5][10][22][53] have found that group learning does not always produce a better outcome than individual learning. A negative group interaction can lead to members associating both learning and social interaction with negative experiences and withdraw from both, potentially even permanently[10]. If the task is not sufficiently defined and structured[5], the individual efforts of learners are not rewarded, and/or free-riders not penalised[22], then group learning can have a negative impact on learning and social development[22][53].

Negative groups tend to not appear in human experiments as they rely on volunteers, which can lead to a volunteer bias, which is a subset of the more general Sampling Bias[102][126]. Volunteers, when compared to non-volunteers, tend to score lower for neuroticism and higher in conscientiousness, agreeableness, extraversion on psychological tests and, perhaps, have a higher need for social approval[81]. These individuals have a tendency of wanting to please the experimenter or be liked by others. This results in positive feedback between group members which can lead to validity problems when applied to real world scenarios where different personality types interact[81]. The importance of identifying "positive" and "negative" groups, or disruptive individuals within a group, and resolving issues before students develop a resistant attitude towards education, social-interaction or both, cannot be understated[10].

2.2.4 Group Behaviour

Forsyth argues that groups are so commonplace that their complexities are overlooked and that a starting place to begin defining groups is with five qualities: interaction, goals, interdependence, structure, and cohesion[41]. Human studies of groups can yield reliable and positive results but suffer from volunteer bias as discussed in Section 2.2.3.

2.2.5 Why Are Groups Different To Collections Of Individuals? Groups Change Individuals

Psychology researchers have found that base personality traits do not tend to change significantly within individuals during their life time, while outward behaviour changes do occur[31][57]. Personality models developed from the work of Costa and McCrea identify two types of personality trait, "Basic Tendencies" (BT) and "Characteristic Adaptations" (CA)[31]. In these types of models, BT are classified as the innate qualities of individuals, which include levels of temperament, intelligence, while CA are personality traits that are caused by the interaction of BT with the environment around them. CA are dynamic depending on the level of environmental change and the individual's BT . In this sense, personalities can be seen as both stable and dynamic, depending on what factors are measured[31][57].

Behavioural change, via measurement of CA, within groups was observed by Triplett in 1898[24]. Triplett demonstrated that participants would work harder and faster in the presence of others, than they would by themselves. More recently, social psychologists have studied direct interaction between individuals and the changes they produce[24]. According to Social Identity Theory, individual identities are formed by the groups they interact with, generating categories of "in-group" and "out-group" for other members of society. Different groups have different levels of social mobility between groups, and perceived legitimacy of others by group membership[2]. In-group/out-group identification with discriminatory behaviour can develop rapidly[118].

Within groups with particularly high levels of group identification, members sometimes will seek group cohesion over critical thinking, wanting the group to agree rather than challenge bad ideas. Some reports have shown that members of these groups were unaware that they could object during group discussion, only thinking critically (on a conscious level at least) after the group was no longer present. This state is known as "groupthink syndrome"[123].

2.3 The Position Of The Teacher Within The Classroom

Student interaction is not the only aspect of group formation and dynamics which needs to be understood as part of generating an agnostic system of monitoring students in the classroom. The position of the teacher as part of that group, either as a direct agent interacting within the group or as an indirect guide will naturally change the interactions within the group itself [47]. When assessing teacher authority, it is important to understand the teachers role in the exchange of knowledge within a classroom environment. This is normally cast into 2 categories, that of teacher-centred learning and that of the Rousseauian/Constructionist student-centred learning[46]. These 2 categories rest on a series of axes including; but not limited to; the level of student choice (low to high), the level of participation a student puts into the learning (passive to active), and the centre of power (teacher to student)[46]. This axis between teacher and student/s can also be expressed as a continuum[98], as can be seen in Table 2.1. The transition of student choice, participation and the centre of power moves from being focused on and around the teacher, as a sole hegemon, to the student, in a multilateral community. Throughout the education system, the continuum transitions from the Lecture model to Self-assessment model. This transition is not linear, moving between more teacher-centred and more student-centred approaches, at different speeds depending on the pedagogy of each teacher and the institutional culture of the education setting.

Table 2.1 shows the instructional continuum from teacher-centred to student-centred lessons. The most teacher-centric lesson type, the lecture, is at the top of the table, with each row becoming progressively less teacher-centric and more student-centric.

The formation and source of knowledge of a student is inextricably linked

Teacher-Centred	
Lecture	Teacher takes an active role and presents information to the entire class while the students main role is to listen to the new information being provided.
Recitation	The classroom interaction follows the specific pattern of teacher initiates a question, student responds and teacher evaluates the response.
Drill and Practice	The teacher provides a series of independent tasks to reinforce a concept.
Demonstration	The teacher helps the students learning by showing him or her how to use materials and special tools, or how to accomplish a particular task.
Discussion	Conversation designed to stimulate students to respond divergently and at higher cognitive levels to what they have been learning.
Cooperative Group	Small group work that features positive interdependence, individual accountability and collaboration skills.
Guided Discovery	The teacher structures an experience or problem for students and provides a series of steps for students to follow to discover the principle, rule or generalization.
Contracts	The teacher and student form a written agreement about what work will be completed and when.
Role Play	Students act out real life dilemmas or decisions to solve problems.
Projects	An investigation is undertaken by a student or group of students to learn more about a topic.
Inquiry	An instructional strategy where the teaching begins with questions and relies on them heavily thereafter as ways to stimulate student exploration, discovery and critical thinking about subject matter.
Selfassessment	The student has responsibility for evaluating his or her own work as a means of learning.
Student-Centered	

Table 2.1: Instructional Continuum

to the authority level of the teacher i.e. the position on the instructional continuum[95]. Audi (2003) reiterates that knowledge is derived from perceptual, memorial, introspective, a priori, inductive, and testimony-based epistemological sources[1]. Perceptual knowledge is constructed from that which one can sense from the environment around them directly. Memorial knowledge is based on the memory of information previously provided. Introspective knowledge sources a formation from within without the need of specialised knowledge beforehand. A priori knowledge is based on definition. Inductive knowledge is the logical extrapolation of data which has been provided. Testimony knowledge is based on receiving of knowledge from other people's experiences. The value of truth assigned to each of these epistemological systems is weighted on the level of trust the subject has in the origin of the knowledge. In regards to education, a student will value knowledge provided from a teacher who is deemed to have higher levels of trust more than knowledge gained from a teacher with lower levels of trust. Each of these epistemological sources of knowledge is then underpinned, according to Audi[1], by a justification framework (i.e. a methodology of how you justify what epistemological source is acceptable. If there is a hierarchy of sources, sources within an epistemological framework are individually rated, etc...). Thus, for each piece of knowledge you believe to be true you have a justification as to why you believe it to be true, that exists both internally and externally to the epistemological nature of that knowledge.

Therefore, a teacher must ensure that students trust the source of knowledge during educational sessions. Higher levels of trust are required in the teacher directly in more teacher-centric lessons (e.g. Lecture or Recitation), and for students to have higher levels of trust in their own ability to examine and understand material by themselves (e.g. Inquiry or Self-assessment).

This research focuses on group based learning scenarios within an educational context placing the classroom structures towards the Student-Centred end of the Instructional Continuum. Therefore the position of the teacher is on the periphery of the group. So while the teacher needs to be part of any group based monitoring system, their role will be conceptually external to the group. However breakdown in groups will require the intervention of the teacher, and meaningful intervention is based on the relationship between students and teacher. Group relationships have the potential to rapidly change the structure of the group before, during, and post intervention and any system will need to be able to react to this change.

2.4 Student Psychosocial Development And Teacher Feedback

To understand the intersection of systems justification theory within a secondary (or lower) classroom with a teacher, this thesis shall examine the transfer of authority within Snell's 2017 study[108]. In a teacher-centric classroom environment, the teacher is the main authority figure. The attribute of authority is transposed on the teacher by both the individual student and the collective whole of the classroom by generating a framework justifying a reason as to why they should select this person as a viable and trustworthy source of knowledge. This framework is then used to justify the epistemological nature of the knowledge transfer within the classroom environment. The role of the student then becomes a passive or semi-passive receiver of information from a source they have justified as trustworthy and thus surrender some degree of autonomy as learners to the instructional teacher (as is the basic tenet of the Rousseau Social Contract Theory[99]). When the source of knowledge is transferred from a teacher-centric to a student-centric model it fundamentally damages the justification model which students have built up in the authority of the teacher, thus degrading the authority of the teacher. This can become problematic due to the psychosocial development level of the students who are using the student-centric learning technology. Both the post-Freudian Erikson's Psychosocial[52] and the neo-Piagetian Kegan's constructive-developmental[69] development models include a stage, coinciding with Secondary Education, where the majority of humans start to define themselves via more complex social roles, transitioning from a needs-based identification of the self to the development of understanding that others have an ego or a self also. Individuals then tend to start to define themselves via the expectations of others and questioning of the identity that, in prior stages, has been generated externally for them via pre-existing social structures (e.g. Government, Religion, Family), rather than internally by them. This identity transition begins, but is limited, during Secondary school and produces its most substantive changes post-adolescence[128] (It should be noted that Waterman's (1982) review of studies focuses mainly on University students). While none of these theories describe the development of the self and cognitive development perfectly, Demetriou, et al.[27] demonstrate that the overall narrative is true and dominate the underpinning of the majority of theories in the field of educational psychology. Tables 2.2, 2.3 and 2.4 show the basic outline of Piaget's, Kegan's and Erikson's theories of child development. It should be noted that where age ranges are given these are merely guides to the ages that the majority of people go through at these stages, and that each stage is not a fixed constant that needs to be completed before progression to the next. Piaget himself stated that the stages were more conceptual guides rather than absolutes and studies have found that the general concept of these developmental stages are universal. Children can exist in more than one stage simultaneously and can begin significantly earlier or later than the ranges stated in the original theories[105]. Student issues with transfer of power structures has also been viewed with first year university students where the sudden shift to student-centred approach caused anxiety at the lack of guidance and a continued belief of the need of a more balanced approach[119]. Post-graduate courses benefit from a more complex model when the student is older and all the students have solidified their cognitive development. Brocato in her work examining a "studio-based learning" or person-centred approach for teaching teachers found that using a propose-critique-iterate stance (similar to the Hegelian thesis, antithesis, synthesis), was effective in embedding person-centred pedagogies within these new teachers[12].

Any system being designed to monitor student well-being within a classroom setting will need to consider the psychosocial development of the student(s) and potential crises that may arise from changes in social hierarchy structures throughout educational institutions. While this research does not explicitly consider the developmental level of the learners it was deemed necessary to cover potential issues that would be dependent on the demographics of the learner population for future systems.

Stage	Approximate Age Rage	Description
Sensorimotor	Birth - 2 years	Learning to control movement, interact with physical world and understand that objects continue to exist without being sensed directly.
Pre-Operational	2 - 7 years	Ego-centric. Development of Language. Basic symbolic representation of real objects - e.g. cardboard tube as a sword. Irreversibility - unable to draw conclusions from reverse order of events. Conservation - unable to see that properties of an object, such as mass, stay the same despite changing shape. Transitive inference - difficulty understanding if A>B and B>C that A>C.
Concrete Operational	7 - 11 years	Foundation of logic inductive reasoning (being able to generalise from specific), but cannot reason with abstract and hypothetical notions. Can understand if A>B and B>C that A>C but may not be-able to answer "is A>C" when asked directly.
Formal Operational	11 years - adulthood	Abstract thought. Metacognition - thinking about thinking. Problem solving through deductive logic rather than trial and error.

Table 2.2: Piaget Cognitive Development[69]

Stage	Maturity Level	Description
0. Incorporative		No sense of Self, purely reflexes.
1. Impulsive	Infancy and Early Childhood	Self identifies through emotions, e.g. "I am tired".
2. Imperial	Childhood and adolescence	Moves from "being needs" to "having needs". Does not yet understand that others also have needs.
3. Interpersonal	Post-adolescence	Social intergeneration of needs, by understanding that others also have needs and balancing the needs of the self and the needs of the other(s).
4. Institutional	Adulthood	Understanding of "Moral" values, i.e. an appreciation of a rules-based system. These rules and values are generated by the society they are born into, not by the self.
5. Inter-Individual	Post-Maturity(?)	Understands (not just knows!) that multiple moral/value systems exist and that one has their own ideology rather than "truth". Creates their own value and moral system. Very Rare!

Table 2.3: Kegan Stages of Adult Development[69]

Stage	Approximate Age Range	Basic Conflict	Success	Failure
1.	0 - 18 months	Trust vs. Mistrust	Sense of Trust	General mistrust
2.	2 - 3 years	Autonomy vs. Shame and Doubt	Sense of autonomy	Shame and doubt
3.	3 - 5 years	Initiative vs. Guilt	Sense of purpose	Sense of guilt
4.	6 - 11 years	Industry vs. Inferiority	Sense of competence	Sense of inferiority
5.	12 - 18 years	Identity vs. Role Confusion	Strong sense of self	Role confusion and weak sense of self
6.	19 - 40 years	Intimacy vs. Isolation	Strong relationships	Weak Relationships and/or isolation
7.	40 - 65 years	Generativity vs. Stagnation	Feeling of usefulness	Shallow involvement in world
8.	65 - Death	Ego Identity vs. Despair	Feeling of wisdom	Regret, bitterness and despair

Table 2.4: Erikson stages of Psychosocial Development[52]

Modern educational authorities, such as the UK's Department of Education, suggest that a good pedagogy includes scaffolding[60]. Scaffolding is an approach in which a more knowledgeable source (e.g. a teacher) guides the understanding of a learner to complete a task which is beyond their current capabilities to solve independently. This could be due to their lack of knowledge within the subject or lack of experience in self-monitoring their understanding. Scaffolding can be divided into two sub categories, "hard" and "soft"[6]. Soft scaffolding is where the knowledge source directly prompts the student towards the answer, in a form of Socratic dialogue, which is bespoke to the individual or group that is doing the learning. Hard scaffolding is where the prompts are pre-determined and provided before the learning session has begun, e.g. a video of an expert talking about how they would attempt to solve a problem or a series of questions written within the problem being set. While this approach of using a problem-based learning scenario, supported by scaffolding, has improved students cognitive skills[6], others have noted that this has come with a cost (e.g. the narrowing of the curriculum and the constant pressure on schools to meet standards of the academic press, concerned more on outcomes rather than just learning)[82]. Within in this research it shall be considered that AI systems will mainly use some form of “hard” scaffolding while a human teacher can employ “soft” scaffolding as a feedback mechanism. Again the type of feedback provided will be dependent on the psychosocial development of the learners and the pedagogy of the human teacher. It would be potentially beneficial to support teacher authority and student learning ensuring that the type of feedback provided by an AI system should be closely related to the teacher’s pedagogy.

2.5 Education Research Within Computer Science

A significant amount of research has been carried out on supporting group work within real world smart environments[45][125], intelligent classrooms[29] digitising of group based educational techniques[65][90] and feedback from members as metrics of satisfaction[37]. Less has been focused on the structure of the group itself. Attempts to capture groups as an entity include aggregating Bayesian Network based individual student models[117], similar to one of the approaches taken by Economists[79]. However researchers in Psychology have shown groups out perform what aggregate models would suggest[35][130] (See section 2.1). The evidence from the research suggests that levels of social sensitivity with equal distribution of conversational turn taking were a better indicator of group performance than individual intelligence scores.[130].

Interaction Between Teacher And Student

One use of technology in an education setting is improving interactions between students and teachers. Large classrooms, both within traditional and e-learning contexts, may have suffered from a lack of interactivity, meaning that lectures can be static and have a significant delay between delivery and feedback on its effectiveness. However, when a teacher can receive instant (or near instant) feedback on how the lesson is going they can adjust the teaching methods to better align with the class they are leading. Wang et al. used interactive polls to gather feedback from students to provide real-time feedback to the teacher on how the students were perceiving the lesson[127]. While these polls were useful for the teacher, they relied on active and honest students pro-actively submitting responses in order for the data being fed back to be accurate.

Enhancing Learning

Another use of technology is Huang (2008) which describes ubiquitous learning (u-learning) as an evolution from electronic learning (e-learning) and mobile learning (m-learning) where students are capable of having a fully immersive learning experience remotely, at a time to suit them[59]. Hwang (2011) reviews the use of u-learning in 2 studies. The first study was an outdoor lesson for students to identify trees, finding them first by utilising a GPS mapping system to find the trees, then using RFID tags attached to the trees themselves to initiate a data upload. Once the student was in range of a tree, appropriate information and questions relating to the species of tree was delivered to the student's hand-held device. This, according to the study, made the activity more engaging for the students and re-enforced the information from the lesson. The second study was an indoor activity, similar to the first, but encapsulated within an English lesson, providing contextual English captions when a student was in range of particular objects[61].

Researched Populations

Populations which partake in these studies as not all methods are applicable to all age groups (see Section 2.4 for details on learning differences between age groups). A 2017 review of journal articles, conference papers, reviews and press articles concerning emergent technology in education located on either the "Web of Science" or "Scopus" databases, published between January 2006 and December 2016, found that of the 288 articles in scope, 52.8% were classified as targeted at students (regardless of the level of education they are receiving), with 16%, targeted at teachers only, and 6.9% targeted at both students and teachers and a further 23.3% targeted at the general population. Of the papers focusing on “teachers”, and “teachers and students” (22.9%), 63.6% were aimed at Higher Education, 16.7% at the general population and 19.7% on Primary and Secondary (3%), Secondary (15%), and Secondary and Higher Education Sectors (1/5%)[89].

Neira (2017) review utilised a keywords search, providing an example of (”emerg* technolog*” OR ”technolog* emerg*”), which would have excluded any documentation that did not use similar phrasing in either the title, abstract or keywords in Scopus or subject in Web of Science. Unless other terms were used which have not been listed in this review then there are papers which, while covering the same topic area, will have been missed. For example Huang 2011[58] uses the phrase ”ubiquitous learning” or ”u-learning”, and while it does focus on emergent technology, the phrase is only used within the text of the main body of the document and not in the locations Neria et al. (2017) utilised when they were selecting documents to analyse. Without a full list of search terms this study cannot be considered conclusive that teachers and non-Higher Education students are-under represented in the research field. A similar review was conducted by Kinshuk, et al. looking at the 20 most cited papers between 2003 and 2010 in the Journal of Educational Technology and Society - which is considered one of leading Social Science Citation Index (SSCI) journals in the field of educational technology.

Of the empirical studies within this time frame only 2 education levels were identified - Elementary School and Post-Secondary or age ranges of 6 to 11 and 18+[73].

Social Interactions

Cherney (2018) conducted a psychology and computer science review paper of group formation and interaction studies for online learning and found support for improved learning outcomes for activities that included social interaction and significant decrease when learners were isolated when compared to traditional settings. While a majority of studies in the review examined some aspect of group behaviour they were mostly focused at the individual level. Cherney notes that most studies on group interaction focus on quantity of interactions rather than quality of those interactions. By counting number of posts during online learning sessions researchers found that active groups became more active when other active members were added to the group. Replacing active members with inactive members did not increase the number of posts made by inactive members, but number of posts increased when members of different cultural backgrounds were added. Apart from number of interactions, quantitative measures also include the number of words per message and identifying social networks which indicate groups or sub-groups forming in collaborative work. In addition groups were found to improve their performance in regards to task completion when groups were allowed to change dynamically rather than static assignment. This analysis of message density and networks formation also shows that smaller groups encourage participation on an individual level even if larger groups show higher levels of participation overall. Cherney also finds support for the work of psychologies (e.g. Tsoukalas (2007)), where groups with better quality of communication between members perform better than those groups with lower levels of quality of interaction and that low performing groups cause negative psychological responses, supporting work by Bartlett (1995), Cohen (1994), and Gunderson (2008)[19].

School students do not always have the tools to know how to regulate social interaction, needing intervention either by a teacher or AI component. Evans et al (2016) used an experimental set up with an interactive table top interface in a traditional classroom setting. The authors defined social regulation as combinations of planning of a task, monitoring of progress and understanding of both the task and plan, and behavioural engagement of ensuring all members perform their roles during the task. With this definition, Evans et al found they could correlate quality and effectiveness of work with various patterns of interactions with the interactive table top. They do note it required more than a pure quantitative approach and that an examination of metacognition is needed[36].

Peer Learning

It is not only the student that needs support during a learning session. Walker (2011) examined the effect of an adaptive prompting system for peer learning, extending it from the prompting system for individual ITS systems. They found that prompts that made the mentor feel accountable for the help they provided the mentee improved overall performance[125].

AI Trends

Chassingo's 2018 review paper on Artificial intelligence trends in education identifies 3 common uses of AI in education[17]:

1. Using ITSs to provide targeted feedback to students to support learning
2. Assessing and tracking student performance
3. Personalised learning & AI robotic replacements for teaching

These trends show a significant progress on supporting, and in some cases attempts to replace, teachers within the classroom. However they do not identify a trend to supporting group work with AI systems, only the increasing efficiency of AI supported one to one learning. The authors also suggest mixing data mining techniques with the Myers-Briggs Type Indicator model[17], a model which finds little empirical support within the psychology literature[93].

2.6 Potential Issues When Introducing Technology In The Classroom

Implementation of digital material into a classroom can cause problems for secondary school teachers as the authority within is transferred from the teacher to the students. In a survey of 4 teachers transitioning from a print to digital curriculum[95], 1 tried to reassert control of the class alongside the digital material, but kept feeling like an auxiliary rather than a teacher but eventually crafted a structure that allowed her to actively engage with the material; 2 ceased using it as a primary teaching tool, but used it as additional learning tools for stronger students reverting to paper versions they had used before. The fourth never fully implemented the digital version due to constraints within the school. While committed students were able to engage pro-actively with both the teacher and the digital material to achieve the learning outcome, others found ways to bypass the learning process by exploiting the monitoring system of the digital material (in this case a series of tick boxes to say you had completed a section)[95]. The authors note, however, that this may be due to the lack of familiarity with the digital material and suggested closer working between developers and teachers, taking more time to familiarise themselves with the material before class to better match it with their pedagogical methods.

Another study by Tyler-Wood et al. (2018) investigated the implementation of the "Solenoid Unit of Instruction" (SUI) at 2 rural schools in Texas.

The study involved 17 teachers who took part in the surveys and approximately 400 students. Teachers showed no significant change in scores on the Concerns-based Adoption Model-Levels of Use surveys (pre-test mean score 5, post-test 5.18[124]), or the Stages of Adoption of Technology (pre-test mean score 4.12, post test 4.53[124]). In addition, the open ended comment section at the end of the survey provided evidence that "some" teachers were unaware that new technology had been provided for them. The authors suggest this was due to lack of technical support staff in rural schools and may have been the primary reason for these results. Student results were compared to other cohorts who did not have SUI implemented into their curriculum. Students with access to SUI showed an increase in test scores in the Trends in International Mathematics and Science Study (a series of international assessments of student mathematics and science knowledge), but showed no significant gains in the SUI achievement test provided as part of the SUI to access knowledge gain. The latter finding differed from an earlier implementation of SUI in a middle school in urban Virginia. However the school in Virginia had longer access to a 3D printer (part of the SUI teaching materials), students were a year older, were taught by an engineer, and were taking a volunteer additional course rather than a compulsory class[124]. Tyler-Wood et al. (2018) conclude that the differences in student interest, teacher knowledge, and both groups familiarity with the technology being used, contributed to this difference.

Both Puttick (2015) and Tyler-Wood et al. (2018) show that additional training and technical support for teachers were needed to improve academic outcomes when implementing technological material into a classroom.

2.6.1 Backlash Against Technology In The Classroom?

It should be considered what the effects are of introducing technology to solve a problem. Neil Selwyn in “Is Technology Good for Education?”[106] argues that often people are attracted to the idea that education is a broken system that needs to be disrupted or undergo a technological revolution in order to be born anew. However, he stresses that while there are many problems with education it does not mean that a) the system is broken or b) that system, by necessity, needs disrupting or overthrowing with technology. Selwyn argues that this is more due to an ideological basis rather than a more scientific and empirical examination of the problem, stating key innovators have a Neo-Liberal approach to markets and education, believing that because they are self motivating and disruptive individuals the solutions to the problem(s) need to exhibit the same attributes. The concept of Educational Emancipation or Liberating the Learner with the self choice of educational pathways, while highly beneficial to the same subset of people as the key innovators that Selwyn refers to, can actually entrench, as oppose to lessen education exclusion[5][10][22][53]. Selwyn states that without mentors to help support and guide a learner through their education the same learners that self-directed educational technology is supposed to help are, in fact, hindered. He continues, stating that this problem is compounded by his perceived use by others of a simplified narrative, and assuming that a technological fix to education is self evident, common sense and should be pursued as such. He rationalises this by invoking the title of his book to point out that there is no simple question that has a simple yes/no answer. The term “good” is, indeed, highly subjective. He argues that rather than assigning value judgements to technology in education, we should, instead, evaluate it using the same methodology as we evaluate forms of education[106]. For this he cites Biesta’s 3 criteria to rate education technology[9].:

1. Qualification - providing people with the knowledge, skills, understanding and disposition allows them to preform specific or general tasks (e.g. professional vs. life skills). This is viewed as one of (if not the) major functions of organised education.

2. Socialisation - becoming well rounded members of society. This imbues individuals with the social norms of the culture that the education exists in. While this can be explicit within the educational institution, it can be part of a ”hidden curriculum” which indoctrinates individuals into culturally specific/acceptable methods of behaviour.

3. Subjectification - a sense of self, or who I am, with the ability to think and act autonomously. This encourages an individual to break from the socialisation aspect of education so they can view a problem outside of the cultural constraints. Not all educational institutions or programs perform this stage.

The conclusions, perhaps, display the internal bias within "Is Technology Good for Education?" by arguing for three starting initiatives to redefine the technology in education debate.

1. An extensive and intensive State/Government involvement in implementing technology within the education system utilising existing pedagogies.

2. Removing speculative profiteering from educational technology, thus making educational technology about improving the educational system as a whole, not for the few or profit margins.

3. Making the use of technology controversial.

This would allow more public engagement with the subject, citing examples such as Genetically Modified Crops or Fracking, thus creating a more complex narrative than he believes is currently present.

2.7 SYMLOG

SYstematic Multiple Level Observation of Groups (SYMLOG) was developed from Interaction Process Analysis (IPA)[4]. IPA was developed by Bales in the 1940 and early 1950s [4][92] and is an attempt to quantify group behaviour by categorising interactions between group members. These categories are not context or content specific allowing them to be applicable in all situations and, with a suitably trained observer[4], encoding the interaction between any group and track the development of the group in a statistical way[92]. These interactions were broken down into 4 categories, 2 Social Emotional (Positive and Negative reactions) and 2 Task Areas (Attempted Answers and Questioning). For example if there is a conversation between 2 people (Person A and Person B) then Person A (or more commonly an external observer) would rate how they perceived Person B behaved and Person B would rate how they perceived Person A behaved. This is opposed to where people self reflect on how they believe others perceive them. Rating of how individuals interact with a group is not one rating for the whole session, but one or more ratings per interaction with one or more other people within the group[4][42][92].

As with IPA, SYMLOG is an attempt to quantify group behaviour by categorising interactions (both verbal and non-verbal) between group members, with each interaction being rated externally, replacing the four categories with 26 adjectives in[42]. The SYMLOG adjectives are listed in Table 2.5. These adjectives are assigned a combination of letters of U/D (Up/Down), P/N (Positive/Negative) and F/B (Forward/Backwards)[42][71]. U/D is the measurement of a person's dominance or submissiveness to the group. P/N is a scale if a person's interactions are friendly or non-friendly within a group. And F/B is a measurement of how the person within the group is working either towards or against either the group goals or emotional status of the group.

When these ratings are collected groups can be assessed by seeing how

Assigned letter(s)	Adjective description
U	Individual financial success, personal prominence and power
UP	Popularity and social success, being liked and admired
UPF	Active teamwork toward common goals, organisational unity
UF	Efficiency, strong impartial management
UNF	Active reinforcement of authority, rules, and regulations
UN	Tough-minded, self-oriented assertiveness
UNB	Rugged, self-oriented individualism, resistance to authority
UB	Having a good time, releasing tension, relaxing control
UPB	Protecting less able members, providing help when needed
P	Equality, democratic participation in decision making
PF	Responsible idealism, collaborative work
F	Conservative, established, "correct" ways of doing things
NF	Restraining individual desires for organisational goals
N	Self-protection, self-interest first, self-sufficiency
NB	Rejection of established procedures, rejection of conformity
B	Change to new procedures, different values, creativity
PB	Friendship, mutual pleasure, recreation
DP	Trust in the goodness of others
DPF	Dedication, faithfulness, loyalty to the organisation
DF	Obedience to the chain of command, complying with authority
DNF	Self-sacrifice if necessary to reach organisational goals
DN	Passive rejection of popularity, going it alone
DNB	Admission of failure, withdrawal of effort
DB	Passive non-co-operation with authority
DPB	Quiet contentment, taking it easy
D	Giving up personal needs and desires, passivity

Table 2.5: SYMLOG Adjectives

well the group is working together by examining the group itself rather than just the outputs from the group, e.g. task completion.

2.7.1 Visualising SYMLOG

The Adjective ratings can be used to create visual representations of groups. The 3 pairs of letters U/D, P/N, and F/B can be used to represent 3 axes between each of these positions. Each of these axes can be given a numerical scale, for example we can assign U to a value of 2 and D a value of 0 creating an axis between 2 and 0 for how dominant (U) or submissive (D) an individual behaves within a group. Using the adjective description "Active teamwork toward common goals, organisational unity", which is is represented by the 3 letters "U", "P", and "F", these 3 letters can be assigned numbers to create a 3 axes (or 3 dimensional) coordinate system, in the case of UPF it would be (2,2,2). These coordinates would then be combined with other ratings (if applicable) throughout group interactions. For example, Person A received a rating of "DPB" (Quiet contentment) from Person B and "UPF" (Active teamwork) from Person C, the U and D values are 2 and 0, which resolve to 1 (i.e. neutral), as does the F and B values. This leaves Person A with an overall rating of "P", represented by the coordinates (1,2,1)

Adjective ratings for each member of the group are collected and plotted onto a SYMLOG Field Diagram (SFD) (Figure 2.1). The P/N resolved rating is plotted along the x-axis and F/B on the y-axis. U/D is represented by the size of individuals point on the graph, the larger the point the more

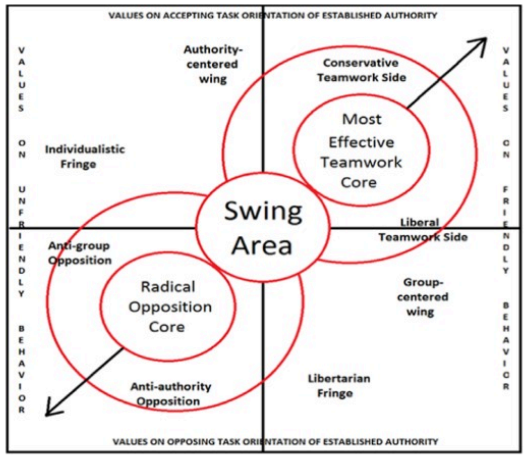


Figure 2.1: SYMLOG field diagram[7]

dominant behaviour each individual was recorded displaying. The SFD can be divided into 4 quadrants by bisecting the x axis at $x = 1$ and the y axis at $y = 1$. The upper right quadrant ($x > 1$, $y > 1$) is where members of a group are recorded with more positive interaction adjectives throughout a session, and the lower left quadrant ($x < 1$, $y < 1$) is where members of a group are recorded with more negative interaction adjectives. These shall be referred to as Cooperation and Non-cooperation areas of the SFD.

2.8 Game Theory

2.8.1 Introduction

Game theory is an area of study within mathematics (and used by economists and political scientists) which builds models of human interaction[49]. While SYMLOG and mod-SYMLOG are useful tools to describe current and historical structure of a group or groups, game theory provides a mathematical foundation for generating predictions on group interaction and potentially academic performance. This predictive ability is tested in Chapter 6 as part of creating an intervention system to assist teachers within a classroom.

2.8.2 Different Types of Multiplayer Games

Game theory has multiple types of games which can be divided into different categories or types of game. Some game types in game theory are[91]:

- Zero Sum games are resource limited games. If one of the players wants to "win" or increase the amount of resources they have the other player(s) will either have less resources or none at all. So the gains of 1 player should equal the losses of the other.

- Plus Sum games, in contrast to zero sum games, allow resources to grow or allow players allocation of resources to be at a cheaper cost to each player.

- Cooperative or non-competitive games are where players are encouraged to work together.

- Non-cooperative or competitive games are where players are encouraged to behave selfishly.

- Simultaneous games are where players all make their move concurrently, or without knowledge of the other player(s) move(s).

– Sequential games happen when each player takes turns making moves, and each player knows what the last move was before they need to decide what move they are going to make.

As with the schools of psychology, the game types are not exclusive. While Game Theory itself is modelling socioeconomic behaviour, the types and combinations themselves can be understood through examples of traditional games. For example, Chess, Noughts and Crosses, and Go are competitive, zero sum games which are played sequentially. Some games can dynamically change, meaning that they can be both Cooperative and competitive. Diplomacy encourages players to form teams and work together against other players, but as the game is a zero sum game (there can only be one winner), it is expected that players on the same team, stop cooperating at some point during the game. More details on Diplomacy can be found in Chapter 4.2.2.

Two classic game theory games are that of Chicken and Prisoner's Dilemma, which will be briefly described below, before introducing the Snowdrift game, which will form the basis of predicting group behaviour (see Chapter 6).

2.8.3 Chicken and Prisoner's Dilemma

Chicken is a zero sum, non-cooperative, and simultaneous game where 2 players compete against each other. The scenario is commonly described as two people in cars, driving head on towards each other, forcing each player to choose to either carry on straight, crashing the two cars together and killing both players, or swerve, avoiding the collision[91]. The choices of each player and the results can be represented on a grid as displayed on Table 2.6).

	Swerve	Straight
Swerve	Tie/Tie	Lose/Win
Straight	Win/Lose	Crash/Crash

Table 2.6: Chicken

Prisoner's Dilemma is a game developed to describe a situation where rational actors might choose to not cooperate, even when it is in their best interest to do so. The traditional example is that 2 suspects are arrested by the police and placed in separate rooms. Each suspect is considered a prisoner and is unable to communicate with the other prisoner. The police only have enough evidence to convict the prisoners of a lesser crime with a small punishment, but the police believe that the prisoners were involved in a 2nd crime for which they would get a greater punishment. The police present the same offer to each prisoner, if they provide the evidence that the other prisoner committed the 2nd crime, they would receive no punishment for the 1st minor crime. So each prisoner has the binary choice of either providing evidence for the other's involvement in the crime (defect), or choose to stay silent (cooperate). The scenario presents 3 possible outcomes:

1. Both prisoners defect and both receive a large punishment

2. One prisoner defects while other cooperates, the defector receives no punishment, and the cooperator gets a large punishment

3. Both prisoners cooperate and both receive a small punishment.

Players can devise a series of strategies, designed to provide them with the best possible outcome of the combination of choices made by themselves and the other player. These outcomes are known as payoffs. Prisoner's Dilemma payoff matrices are sometimes represented with the letters R S T and P, where $T > R > P > S$ [91](see Table 2.7 for the matrix). These payoffs can be given a numerical value allowing for various strategies to be compared across multiple games. Table 2.8 provides example payoff values which will be used in Chapter 6 when comparing Prisoner's Dilemma strategies with Snowdrift. For example, using the payoffs in Table 2.8 if Player A chooses to Cooperate and Player B chooses to defect, then Player A sores -100 (a large punishment) and Player B receives a large reward (300).

	Coop	Defect
Coop	R/R	S/T
Defect	T/S	P/P

Table 2.7: Prisoner's Dilemma

	Coop	Defect
Coop	200/200	-100/300
Defect	300/ -100	0/0

Table 2.8: Prisoner's Dilemma Payoff Matrix

Both Chicken are Prisoner's Dilemma were commonly used by political scientists to describe interactions between international actors, from the individual decision making of Thucydides during the Peloponnesian War, as outlined in the Melian dialogue[30], to events during the Cold War period(s) modelling conflict and negotiation between the United States of America (USA) and the Soviet Union (USSR)[109]. One example is the 1962 Cuban Missile Crisis, where the USSR installed a series of nuclear missile launching systems on Cuba (claiming it was to defend Cuba from US aggression). On 15 October the USA confirmed that the USSR had deployed nuclear missiles and support facilities to Cuba. Between 16 October and 28 October, a series of aggressive moves were made by the USA and USSR, with the deployment of navies, aggressive aircraft manoeuvring, and increasing rhetoric from both sides, and the launch of a USSR nuclear torpedo from USSR submarine B-59 narrowly averted when 1 of the 3 senior officers, Vasili Alexandrovich Arkhipov, refused to authorise the attack. The crisis ended when Krushchev (leader of the USSR) "swerved" and agreed to remove nuclear capabilities in Cuba, in exchange for a similar removal of US missiles from Italy and Turkey[38][104]. While it is commonly thought that the Cuban Missile Crisis was a series of games of Chicken, with the cost of nuclear war being the "crash" scenario, Snyder (1971) argues that the US decision makers conceptualised it as game of Prisoner's Dilemma, as they calculated that a series of small risks (including the invasion of Cuba) as minor defections, as both sides wished to cooperate overall[109].

2.8.4 Snowdrift

While Chicken and Prisoner's Dilemma remain popular, this thesis will focus on the Snowdrift Game, which is a cooperative game where the entire group benefits from the interactions of individual members within that group. While not all members of a group will cooperate, all of the group members will benefit from the work done by all of the cooperating members[51][103][110]. Some researchers have argued that Snowdrift games are a more accurate model of real-life group cooperation[103][110]. One common example is that of a snowdrift on a road. Drivers have the choice to either dig the snow away (Cooperate) or stay in their car (Defect). Once the road is cleared, all the people are able to continue their journey, and thus all win the game. As can be seen in Tables 2.9 and 2.10, where as long as 1 or more people cooperate (try and clear the snow), everybody, including the defectors, win. Defectors win at a lower cost than Cooperators who did the actual work[103][110].

A plus sum game that rewards cooperation corresponds with Wolley's[130] findings of a collective intelligence, where groups that have high levels of cohesion, motivation and satisfaction could out perform, academically, the results of any individual within a group (see Section 2.2.1). This social cohesion comes as a result of cooperation between group members, a cooperation built on positive interactions leading to increased motivation and satisfaction. These positive interactions can be measured via SYMLOG (see Section 2.7) and modelled as either cooperation or defection actions via a Snowdrift model. Both SYMLOG and Snowdrift are extended within this research in Sections 3.2 and 3.3 as Mod-SYMLOG and Mod-Snowdrift respectively. This is used in Chapter 6 as a tool to model interactions of groups, a proxy of performance of a group, and for testing of visual representations of group interaction and performance.

	Coop	Defect
Coop	R/R	S/T
Defect	T/S	P/P

Table 2.9: Snowdrift

	Coop	Defect
Coop	200/200	100/300
Defect	300/100	0/0

Table 2.10: Snowdrift Payoff Matrix

Chapter 3

Modelling Group Dynamics in an Intelligent Classroom Tutoring System

3.1 ICTS

3.1.1 Introduction

This chapter will outline the framework of the Intelligent Classroom Tutoring System (ICTS). The ICTS attempts to extend the Intelligent Tutoring System (ITS) model from a single learner to a group of learners and supplement human teachers within a traditional classroom environment. This group understanding with complexities of hierarchies and inter-person interaction is measured using modified SYMLOG (mod-SYMLOG) derived from Psychological theories of Intra- and Inter-group dynamics (see section 2.2.1) and will be constructed via the use of monitoring tools within an immersive or virtual classroom. Section 3.1.2 will provide a brief overview of the current ITS before outlining the ICTS in Section 3.1.3. Section 3.1.4 outlines the theoretical AI systems with the ICTS supporting a human teacher (First Teacher) within the classroom. The Second Teacher is the representation of the AI systems in the current ICTS and the Third Teacher is the AI system observing and interacting with groups within a classroom and the Group User Interface. Sections 3.1.5 and 3.1.6 incorporates psychology and education research on groups to build a Group Model (in the case of Section 3.1.5) and the dynamic lesson structure (outlined in Section 3.1.6).

The proposed system will provide students with new knowledge as part of the educational process. Then test the students on the new knowledge gained. The results of this knowledge will be updated as both part of an individual student's learning but also as part of group based learning during group based educational activities. Alongside this the system will monitor the mental and social well being of the individuals and groups within the educational setting and will attempt to support this well being with interventions and update the human teacher with this information to allow them to best judge when to intervene within a group if necessary.

In Section 3.2 the modifications made to SYMLOG (mod-SYMLOG) and the visual representations derived from this modification are discussed in Section 3.2.1. Finally in Section 3.3 modifications to Snowdrift (mod-Snowdrift) are introduced allowing for a more nuanced rating of group interaction and allowing for predictions of future group behaviour.

3.1.2 Intelligent Tutoring Systems

A traditional Intelligent Tutoring System (ITS) follows a structure of building a knowledge set for an individual learner (Student Model) and processes this information to determine the most suitable method to instruct the student from a series of either pre-defined or adaptive teaching techniques (Pedagogical Model). The pedagogical method(s) instructs how the subject knowledge (Domain Model) is to be delivered to the learner to best meet their educational needs. The delivery of this knowledge is presented via an interface with the learner (Communication Module), then depending on the responses from the learner, the student model is updated and the process is repeated[100]. See Figure 3.1 for illustration of current ITS frameworks. This paper will extend this model from the individual ITS into a group based ITS which is termed an ICTS. The classroom within this theoretical model will be transformed from a static learning space into an augmented learning interface, monitoring and assisting individual and group learning needs. Rather than replacing the teacher, this model seeks to keep the teacher as an integral and central component of the system.

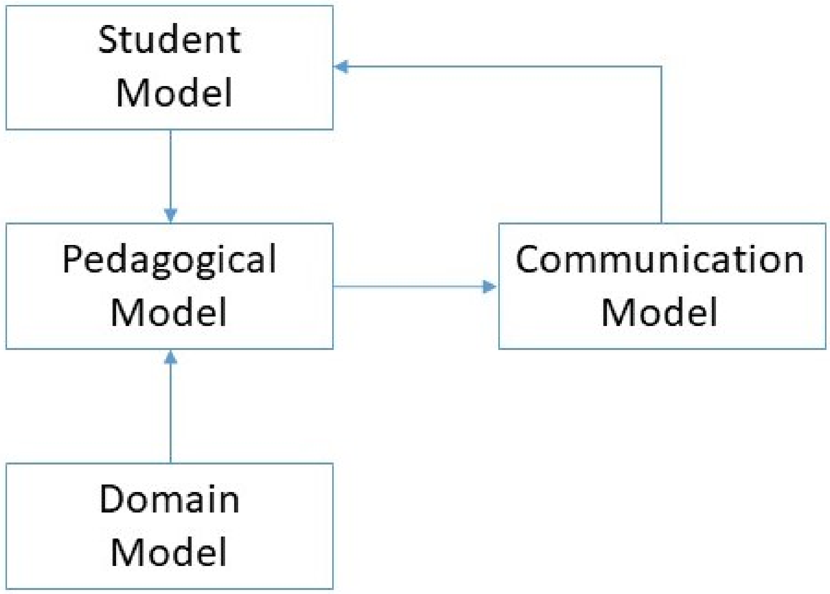


Figure 3.1: Individual Intelligent Tutoring System

3.1.3 Intelligent Classroom Tutoring System Overview

The ICTS model (as shown in Figure 3.2) is an attempt to extend the ITS model from a single learner to a group of learners. The aim is to take the current traditional physical classroom/lecture theatre which is found within a school or university and use that environment to assist a human teacher in delivering knowledge to the learners. The ICTS is split into two components, (1) the individual ITS component, which is the existing ITS model, and (2) a group component. Each component of the ITS is reflected in the ICTS, but dedicated to service a group learning session (see Figure 3.2). The group model represents how the group is interacting as well as showing their academic progress (see Section 3.1.5). The Group Pedagogy Model, which defines how learners will interact with the material (see Section 3.1.6), and the Group user interface, where feedback is provided to the group (see Section 3.1.8). Sections 3.1.7 and 3.1.8 will outline how the human teacher will interact with groups within the system framework.

This is followed by the modifications made to SYMLOG and the visualisations

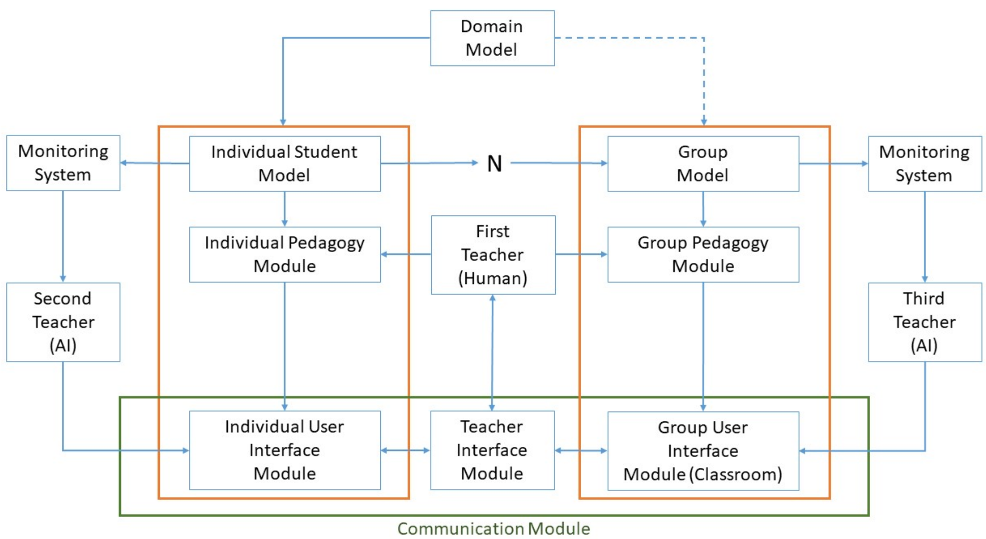


Figure 3.2: Intelligent Classroom Tutoring System Framework[80]

3.1.4 First, Second And Third Teacher

The First Teacher is the senior designer and authority of the classroom. Traditionally this would be a classroom teacher but can also be a supervisor or other such person in an educational role who plans and partakes within a lesson. The First Teacher is still human within the ICTS framework.

The Second Teacher is an AI that monitors or receives information from a monitoring system adjusting the individual user experience based on not only the academic performance of the learner but also their emotional state. This Second Teacher is the AI in a traditional ITS.

The Third Teacher is the "environment as teacher", identified within the Reggio Emilia approach [116] as an educator alongside the teacher and the parent. This environment as teacher is used to inspire and direct student learning through the use of external stimuli, such as visual, tactile, auditory, and olfactory stimuli, designed to direct the learner within a task with or without direct interaction from the teacher, as it is the room itself that "speaks" to the learners[116]. Within the ICTS framework the Third Teacher is the AI which manipulates the classroom environment, (i.e. the group user interface), in a similar method as the Second Teacher, to both support the emotional state of the group, and to assist with defining the narrative of the lesson via the Group User Interface. As part of this the Third Teacher will also monitor the emotions of the group and the academic performance of the group.

The Second and Third Teacher AI should not be considered as individual AI systems, but two collections of AI tools (monitoring, decision making, interface manipulation, etc...) which are interacting together in order to achieve the objectives set out within the ICTS framework.

All 3 Teachers are responsible for monitoring the emotional state of learners, with the AI components of the Second and Third Teachers monitoring and informing the First Teacher. All 3 interact with students and identify which emotional state the learner or group is currently undergoing. The interplay of this emotional relationship with learning is a significant indicator of academic performance and depth of understanding of the subject matter they are being taught[122].

3.1.5 Group Model

As discussed in Section 2.2.4 groups are complex and dynamic. Groups are more than a collection of individuals. They generate a network of direct, indirect or the potential for interdependent relationships. Each variation directly and indirectly affects the behaviour of each individual within the group. Each group is uniquely based on the individuals involved within each group and the strength of group cohesion, relationships, and power structures within that group[41]. The structure of the group will, as in the individual ITS model, inform the selection of group pedagogy which the teacher will utilise for the transfer of knowledge.

The Group Model is an attempt to capture and manipulate Group Cognition (GC). As discussed in Section 2.1 GC is different from Individual Cognition (IC). While GC is dependent on IC, a higher level of argumentative structure combined with a greater zone of proximal development can be observed within a group than within the IC of members[113]. Group cohesion is dependent on the creation of group practises, which are adopted or rejected by the GC[114] .

The Group Model is not designed to be static or employed throughout an entire learning session. Rather the Group Model is dynamic, being created or recalled when needed. Depending on the First Teacher's pedagogy a group of learners may be subdivided into temporary work groups for a section of a lesson, then either redivided or reassembled back into the starting group. The First Teacher could also divide the class into learning styles, or levels of academic performance, depending on how they wished to monitor or tutor various sections of the group.

The Group Model is explored in Chapter 4 using both an AI-based approach with the computer game Europa Universalis 4 and with human participants using the board game Diplomacy.

3.1.6 Group Pedagogy

The direction of the knowledge flow, either from the teacher directly or via self learning and other students, can be expressed as a continuum, where a teacher transfers the responsibility of generating ideas and knowledge towards the learner[98] (See Table 2.1). The ICTS Group Pedagogy Module is based on how the First Teacher wishes to construct the lesson depending on how the groups are formed as part of the Group Model.

3.1.7 Teacher Interface Module

Emotional and academic profiles of groups and individuals are displayed for the First Teacher during learning sessions, with the Second Teacher interpreting the data for individual students and the Third Teacher for the Group Model which is based on mod-SYMLOG. This is a private transfer of data, to protect individual and group confidentiality, and done in a manner best suited for the individual First Teacher's preference and dependent on sub-state, state, and supra-state laws. Possible examples of user display include a standard computer terminal that only the First Teacher has access to or using wearable technology, such as a head-mounted optical display, which provides either visual or audio feedback. The First Teacher can then decide how to best act upon the information they receive. This can be either by the First Teacher interacting with learners directly or utilising the Second or Third Teacher, who are also reacting to input from learners.

The Teacher Interface is tested in Chapter 6 Experiment 3 where participants are asked to rate the level of group interaction as part of a modified snowdrift game.

3.1.8 Group User Interface Module - The Classroom As Interface

The premise of the Classroom as a Group User Interface is the idea of an invisible and/or transitory user interface that allows the transfer of knowledge to a group of learners and student feedback to the First Teacher. This interface is the physical component that the Third Teacher utilises to interact with the classroom. This can be done via modifying the environment of a room to either stimulate learning outcomes, act as an intermediary between knowledge and the learner and/or assisting the First Teacher to direct learner attention and support the lesson plan. The Group User Interface is discussed in Chapter 7 as part of the discussion of future work.

3.1.9 Communication Between Modules

In Figure 3.2 the ICTS is divided into several sections, some of which overlap in the form of a conceptual framework. The components of the ICTS are listed below, divided into sub groups, to assist with explaining the communication between modules.

1. The source of subject knowledge to be given to students
    - (a) Domain Model
2. Individual element which deals with the teaching of individual students
    - (a) Individual Student Model
    - (b) Individual Pedagogy Module
    - (c) Individual User Interface Module
3. Group element which deals with the teaching of groups of students

   (a) Group Model
   (b) Group Pedagogy Module
   (c) Group User Interface Module (Classroom)
4. Communication Module where learners and teachers interact with the system
   (a) Individual User Interface Module
   (b) Teacher Interface Module
   (c) Group Interface Module (Classroom)
5. Monitoring systems which observe aspects of learners experience
6. First Teacher (Human) who is responsible for the learners
7. Second Teacher (AI) who is responsible for the learning of individual students
8. Third Teacher (AI) who is responsible for the learning of groups of learners

The Domain Model (1a) holds the knowledge which is filtered through the Individual (2b) and Group (3b) Pedagogy Modules, preferably using a pedagogy/pedagogues of the First Teacher's (6) choosing. The knowledge (1a) is then communicated to learners either via the Individual User Interface Module (2c) or the Group User Interface Module (3c). Learners will respond to the lesson through the Communication Module (4) via the appropriate user interface (2c) or (3c). The academic results of the individual learner or group from the lesson are used to update and track the progression of the learners. These updates are stored in the Individual User Model (2a) and the Group Model (3a) as appropriate. When groups are formed, information from the Individual Student Models (2a) of each of the group members are used to inform the Group Model (3a). Both individual learners and groups of learners are monitored by a Monitoring System (5) which records both the academic performance of the learners or the group (as part of the transfer between Communication Module (4) to the Individual Student Model (2a) or the Group Model (3a)) and monitors the emotional state of the individual or group. These monitoring systems are controlled by the Second Teacher (7) for the individual student and the Third Teacher (8) for group interactions. Both the Second Teacher (7) and the Third Teacher (8) can update their respective communication modules to support both the emotional state and assist with the academic performance of the group via the Individual User Interface (4a) for the Second Teacher (7) or the Group Interface Module (4c) for the Third Teacher (8). The information about the individual learners or groups of learners can be viewed by the First Teacher (6) via the Teacher Interface Module (4b). The First Teacher (6) can also instruct the Second (7) and Third (8) Teachers via the Teacher Interface Module (4b) as a manual intervention to support individual or group learning activities.

3.1.10 ICTS Example Scenario

An example of how an ICTS could operate in a classroom environment with a group exercise will be outlined here.

In a introduction to databases course a lecturer (First Teacher) selects scaffolding as the pedagogy via the Group Pedagogy Module and then splits the students into multiple small groups of students. Once the students are in groups, the Monitoring System identifies the students and updates the Group Model with the group members and starts to record interactions between them, updating the Group Model with academic progress and social interactions. Materials are delivered to the students via the Group User Interface Module, in this case text and images are projected onto an interactive touch table. The information that is delivered is mediated by the Third Teacher (during group activities) and the Second Teacher (during individual activities), with starting knowledge provided by the First Teacher and Domain Model. The students are asked to create a database in 3rd Normal Form and populate it with provided historical examples of women in STEM fields and are provided with a name, date of birth, country of birth, date of death (if applicable), and a short biography with the subjects the scientists contributed to within the text.

This scenario will now outline the results of 2 groups, Group A and Group B.

Group A

Group A is a cooperative group with interactions which are positive, working towards completing the task, and leadership roles are divided equally among group members. The Third Teacher continuously updates the group model to reflect the level of cooperation. The students start designing relations (tables), the tuples (rows) and the attributes (fields), however Group A only create a single relation to store all the data on. The Third Teacher records this and displays a record of Marie Curie highlighting the words “physics” and “chemistry” in her biography which prompts more discussion within the group leading them to create a 2nd relation containing subjects that the scientists contributed to and eventually design a 3rd Normal Form database for the task.

Group B

Group B is a non-cooperative group, with half the group trying to work on the exercise and the the other half of the group being disruptive. The Third Teacher updates the Group Model and sends an alert to the First Teacher via the Teacher Interface Module notifying that the group has low levels of cooperation, the First Teacher decides to let the group work for a little longer before intervening. After a few minutes an argument breaks out in Group B as 1 of the members who has been trying to complete the task set claims to be unable to work with the constant disruption from the other group members. The Third Teacher sends another alert to the First Teacher via the Teacher

Interface Module, which changes the colour of light being emitted from the interactive table from a standard white to a soft blue in an attempt to create a more calming atmosphere (See Section 7.2.4). The First Teacher intervenes and resolves the issues in the group by rearranging 2 other groups, splitting up the disruptive members and replacing them with individuals from other groups. The Third Teacher updates the Group Model for each of these new groups and the lesson continues.

These two scenarios provide examples of how the ICTS would operate within a classroom environment. The Third Teacher can be more passive or more active for both how to provide knowledge to the students and how to deal with group breakdowns depending on the preferences of the educational institutions using such a system.

3.2 Modified SYMLOG

The Group Model uses mod-SYMLOG methodology which is based on SYMLOG (see Section 2.7 for more details on SYMLOG) as a starting point for understanding group behaviour. It is proposed that this modification of SYMLOG will assist the Third Teacher AI system in modelling groups in games and improve monitoring of groups in an educational setting to minimise negative outcomes.

Mod-SYMLOG replaces the adjective rating system (see Table 2.5) with ratings based on the three axis points, U/D, P/N, and F/B. This is a change from SYMLOG where adjectives are used to describe how the receiver (Person A) of an action interprets the action (from Person B) which are then plotted as individuals within a group to set points within a diagram. Mod-SYMLOG rates these same interactions based on the three axis, one rating for U/D, one rating for P/N, and one rating for F/B.

In this system, Person A would rate Person B on each of the following scales:

– U/__/D: Dominant, Neutral, or Submissive

– P/__/N: Positive, Neutral, or Negative

– F/__/B: Working towards group goals, Neutral, or working against group goals

Therefore if Person A thought Person B was being Dominant they would record "U," and the coordinates would resolve to (2,1,1) as per the coordinate system explained in Section 2.7.1. If Person A thought Person B was being Positive at the same time, Person A would record "UP" (2,2,1). If Person A thought that Person B was withdrawing from the group and being negative and actively working to disrupt the group, Person A would record "DNB" (0,0,0).

Person A could also rate someone as being partially within these axes. For example if Person A thought that Person B was being submissive, but only slightly, and working towards the group goals they would record "DF, F" which would resolve to the coordinates (1.5,1,1).

Mod-SYMLOG is tested in Chapter 4 as part of the experiments for the Group Model (Section 3.1.5).

3.2.1 Visualising Mod-SYMLOG

Due to the changes made with mod-SYMLOG, the standard Two Dimensional SFD was extended into Three Dimensions (3D-SFD), where the U/D, P/N, and F/B are represented on the X, Y and Z axes respectively. This 3D visual representation of the classroom is part of the Teacher Interface Module of the ICTS Framework. Here effective teamwork and opposition/destructive groups/group members areas exist, approximately, within either a green or red sphere, mapped to the Teamwork and Opposition areas of the SFD. Each axis on the 3D-SFD is given a numeric range between 0 (D,N,B) and 2 (U,P,F). Examples of these can be found in Figure 4.2

Finally, node diagrams are used to represent interactions between individual members of the group. These interactions are assigned binary values of positive or negative for the experimental work in Chapter 4, and refined to include light cooperative and light defector in Chapter 6.

Visualisations of mod-SYMLOG are found in Chapter 4 as representations of results from the AI-based and Human-based experiments, and tested in Chapter 6 as part of the mod-Snowdrift experiment.

3.3 Modifying Snowdrift

Snowdrift allows us to observe binary cooperation and defection between members of the group. However, not all group members will be viewed as being cooperative, i.e. not all members of a group contribute the same amount when trying to achieve the group objectives. This research proposes extending Snowdrift to allow for a range of cooperative and defecting actions. In Chapter 6 mod-Snowdrift provides 4 options for a player to choose during a game of modified Snowdrift, by splitting Cooperators into two different groups: Hard Cooperators (HC), which is normally classified as Cooperators (C) in the classic Snowdrift game; and introducing Light Cooperators (LC) as part of our modified Snowdrift game. Similarly, there are Hard Defectors (HD) and Light Defectors (LD).

		Cooperate	Cooperate	Defect	Defect
		Hard	Light	Light	Hard
Cooperate	Hard	R/R	RH/RL	TH/SL	S/T
Cooperate	Light	RL/RH	RR/RR	SS/TT	TL/SH
Defect	Light	SL/TH	TT/SS	PP/PP	PH/PL
Defect	Hard	T/S	SH/TL	PL/PH	P/P

Table 3.1: Modified Snowdrift

Table 3.1 shows the new payoff matrix. The payouts for HC and HD remain the same as the C and D options (see Table 2.10) as in the classic Snowdrift payoff matrix (see Section 2.8.4). Table 3.2 shows the payouts for the combination of options. When there is at least 1 HC action, the maximum payoff of 400 can be split between each player, while if the most cooperative play is LC the maximum payoff is limited to 300 points to reflect the lower rewards for each player. It is assumed that if players put less effort into a game their rewards would be lower than if they had put more effort in. Light actions (LC and LD) are awarded a lower cost to undertake such actions than Hard actions (HC and HD). This is from the assumption that there is a higher cost to doing an activity. In this case the Light actions are 25 points cheaper than the Hard actions.

		Cooperate	Cooperate	Defect	Defect
		Hard	Light	Light	Hard
Cooperate	Hard	200/200	175/225	150/250	100/300
Cooperate	Light	225/175	150/150	125/175	100/200
Defect	Light	250/150	175/125	25/25	0/25
Defect	Hard	300/100	200/100	25/0	0/0

Table 3.2: Modified Snowdrift Scores

These payouts can be used to generate predictive models of how groups will interact in the future, as explored in Chapter 6, where various AI strategies play a series of Prisoner's Dilemma and modified Snowdrift games. These AI strategies are ranked for each game framework and a selection of the best and worst performing strategies in the modified Snowdrift games are used to investigate when humans stop interacting with these strategies as part of a Snowdrift game. Chapter 4 uses modified Snowdrift scores to examine interactions between players in the game Diplomacy, introducing both an individual score for each participant and presenting the possibility of a group score for the collective work of players. Additionally the scores (or player options) can be used to generate node diagrams which are used to test the Teacher Interface Visualisations in Chapter 6.

Chapter 4

The Group Model (Mod-SYMLOG)

4.1 Introduction

This chapter outlines 2 experiments using the mod-SYMLOG framework as part of the testing of the Group Model. The first experiment is an AI-based experiment which examines the generation of visual images as a tool to understand group behaviour within these systems. The second experiment uses human participants, with the control groups using SYMLOG, and the experimental groups using mod-SYMLOG. This second experiment is designed to validate mod-SYMLOG.

4.1.1 Research Questions

1. Can either Europa Universalis 4 or Diplomacy be used in order to test mod-SYMLOG?

2. Can mod-SYMLOG capture the interactions between groups?

3. Can mod-SYMLOG capture the formation of sub-groups?

These research questions seek to identify a controlled environment to test the mod-SYMLOG framework and validate the mod-SYMLOG system. These questions can then be operationalised into hypotheses:

1. Europa Universalis 4 a valid simulation of human group formation

2. Diplomacy a valid simulation of human group formation

3. Europa Universalis 4 a more valid simulation of human group formation than Diplomacy

4. Interactions between individuals accurately recorded by mod-SYMLOG

5. Interactions recorded by mod-SYMLOG are sufficient to identify the formation of sub-groups

4.2 Methodology

4.2.1 Phase 1: AI vs AI, Europa Universalis 4

Phase 1 utilised the grand strategy computer game Europa Universalis 4 (EU4). Here standard SYMLOG was used for analysing interactions between players, and the generation of standard SYMLOG visualisations (which are discussed in section 2.7.1) for comparison with new variants 3D-SFD and node diagrams.

The first experiment was AI-based with the computer game EU4. Set between the years 1444 CE and 1820 CE, EU4 is a grand strategy game which allows players to role-play 1 of nearly 800 countries, from anywhere in the world which existed between that time frame (and several "Easter Egg" countries that did not exist during that time period). Players control the political, military, research, and economic decisions of a country[62]. The game version was version 1.25.1 and included all 13 Downloadable Content available at the time (up to "Rule Britannia"). The initial game is set up as follows:

1. Open Main Menu options.
   - Autosave Interval set to Five Years.
   - Compress Autosaves unchecked.
2. Start a Single Player game.
3. Start Date set to November 11, 1444.
4. Country selection of Bhutan. This was chosen due to the remote location of the country.
5. Single Player Options.
   - Difficulty set to Normal.

  - Lucky Nations set to Random. This was to allow some additional differences in AI behaviour on multiple replays.

6. Start Game in Normal Mode. This sets the save files to be unencrypted.

7. Once game has loaded open console and type "observe" to enter observer mode.

The save files were collected for each 5 year period for a record of each country's interactions with another. The top 10 countries were selected from each time period. Countries were assigned by ranking all countries by the number of territories they controlled, which is the same scoring system that would be used in Phase 2. The diplomatic relationship between these top 10 was then used to generate SYMLOG ratings between only these countries.

SYMLOG adjectives were matched to diplomatic states within the game. EU4 diplomacy is a complex system based on opinion, attitudes, reputation, trust and relationship types. Opinion is determined by a series of modifiers that range between +200/-200. Relationship types are also influenced by what attitude types are available. For example, 1 country can have attitudes towards another country including friendly, protective, threatened, hostile, and neutral. Vassals of the same country have different relationship types including loyal, disloyal, and rebellious.

Some examples of mapping can be seen in Table 4.1.

The experiment was run a total of 4 times, twice at normal difficulty and twice at very hard difficulty. Each difficulty option (very easy, easy, normal,

Relationship type	SYMLOG
Loyal vassal to Overlord	UPB
Overlord towards loyal vassal	DPF
Rival countries	UMB

Table 4.1: Example EU4 Relationship Types And Assigned SYMLOG Values

hard, and very hard) provides different bonuses to either the human at very easy and easy difficulty levels, and for the AI players when selecting hard or very hard difficulty. By running the experiment with different difficulty settings, and the random seeds provided by the game code, the AI behaviour will change and generate different social groupings in each play-through.

In addition, to test the validity of the SFD, 3D-SFD, and node diagrams, 4 EU4 players were recruited, all of whom where male and of European origin. The experiment was split into 2 parts. In part 1, they were provided with diagrams for every 5 years between 1450 and 1500 and were asked to describe the events that had happened within the game and plan their next moves for the next 5 - 10 year period of the game. In part 2, the 1500 save game was loaded and each participant was asked to compare their assessment of the situation and if they would change any of their plans. (Sample code can be found in Appendix A).

4.2.2 Phase 2: Human Vs Human, Diplomacy

Phase 2 consisted of 2 sets of experiments. In each set the participants played a board game known as Diplomacy. This first set was a pilot experiment which was designed to test the applicability of SYMLOG within the game set up and to run an initial analysis of results to provide a baseline for comparison for the Mod-SYMLOG methodology which would be tested in the second set of experiments for Phase 2.

Developed in the mid-late 1950s, Diplomacy is a turn-based game where participants take the part of the “Great Powers” of Europe in 1900. Each game year consists of 2 phases (Spring and Autumn), and each phase has a negotiation turn followed by a movement turn where all participants move simultaneously. At the end of the Autumn phase, participants either gain pieces or lose pieces depending on the outcome of the Spring and Autumn phases.

The board is a map of Europe, divided into 56 land regions and 19 sea regions. 42 of the land regions are divided between the Great Powers at the start of the game, leaving the remainder as neutral land regions. All sea regions are considered neutral. 34 land regions contain supply centres, 22 belonging to Great Powers, 12 in neutral land regions. Each supply centre provides the player with 1 unit (e.g. if a player controls 4 supply centres they can have 4 units on the board). The winner is the first to control 18 supply centres[13].

In the experimental set up, each participant was asked to fill out a Negotiation Log after each Negotiation turn. The Negotiation Log asked each participant to describe their current diplomatic status with other participants. Table 4.2 shows an example of the diplomatic status section of the Negotiation Log.

Alliance	None
Non-Aggression Pact	None
Cooperative Other	FRA, ENG
War	None

Table 4.2: Austro-Hungary Diplomatic Status

Participants then filled in the number of interactions they have had with each other participant and the SYMLOG rating for each. SYMLOG ratings were provided to participants on a separate sheet of paper. An example of this can be seen in Table 4.3. In this example, the Austrian Player rated England and France as “Active teamwork toward common goals, organisational unity” which is represented by the SYMLOG notation “UPF.” Russia was rated as “Responsible idealism, collaborative work” (PF). Turkey was rated as both “Passive non-co-operation with authority” (DB) and “ejection of established procedures, rejection of conformity” (NB).

Country	SYMLOG Rating
England	UPF
France	UPF
Russia	PF
Turkey	DB, NB

Table 4.3: Austro-Hungary SYMLOG

In the pilot experiment 5 participants, out of a maximum of 7, took part in the experiment which ran for 3 hours on the evening of 14/01/2019. The subject group consisted of 3 males and 2 females, with 2 subjects of Arabic descent and the rest of a White British background. 3 participants were undertaking PhDs in Computer Science, 1 had completed their PhD in Computer Science, and 1 had just started a BSc in Mathematics. Due to the number of participants, the 5 player variant of Diplomacy was selected, meaning that Austro-Hungary, England, France, Russia, and Turkey would be taken by participants while Italy and Germany would remain neutral. Each country was randomly assigned to each participant.

The participants, in conjunction with playing the game, filled out a Negotiation Log at the end of each negotiation phase, recording current and established agreements between participants and using the SYMLOG adjective rating system to score interactions they had with other participants.

Thus each year would cycle through the following steps:

1. Spring Negotiation

   – This is where each participant can choose to engage in open ended discussions with any of the other participants. All of these negotiations happen simultaneously, between any number of players, and can be conducted in private or in public. Spying and deception are allowed. There are no rules on what can be negotiated as it is up to every player to decide what is acceptable or not. This can include in-game exchanges (e.g. the participant playing Russia could agree with the participants playing Austro-Hungary and Turkey on how to share the neutral countries of Serbia, Romania, Greece, and Bulgaria to avoid early game conflict) or non game exchanges (e.g. the English player can offer to buy the French player drinks after the game if they ally against Germany). None of these agreements are considered binding and can be broken at any point during the game.

2. Fill out Negotiation Log

   – Here the participants fill out the log of the conclusion to the negotiations outlining diplomatic statuses with the other participant (see Table 4.2) and the SYMLOG adjectives of how they viewed the other participants during the negotiation phase (see Table 4.3).

3. Order Writing

   – As each country's orders are played out simultaneously the moves by each country are written out in secret and given to the games master (GM).

4. Order Resolution

- Once the GM has received orders from all participants, the GM then moves the armies and navies of each country. Once all the moves have been made, the GM then decides the outcomes of any conflicts based on the rules of the game. Conflicts are resolved by which country has the greater total amount of armies and navies moving or supporting a move into a region.

5. Retreat and Disbanding

   - At the end of the Order Resolution phase, the GM decides how many (if any) units need to retreat from a region or be destroyed (if there is no possible retreat available).

6. Autumn Negotiation

   - This phase is the same as the Spring Negotiation phase

7. Fill out Negotiation Log

   - This phase is the same as the previous Fill out Negotiation Log phase

8. Order Writing

   - This phase is the same as the previous Order Writing phase

9. Order Resolution

   - This phase is the same as the previous Order Resolution Log phase

10. Retreat and Disbanding

    – This phase is the same as the previous Retreat and Disbanding Log phase

11. Gaining and Losing Units

    – In the final phase of the year, each country compares the number of supply centres they control and the number of units they control. If they have more supply centres than units, they can add new units (up to the total number of supply centres) to supply centres within their original country's borders. If they have more units than supply centres then that country must remove units from the game board unit the number of units matches the number of supply centres.

4.2.3 Phase 2, Experiment 2: Mod-SYMLOG

The control experiment using SYMLOG established Diplomacy as a suitable setting for cooperative and non-cooperative group interaction. The second experiment incorporated the adjustments to the SYMLOG framework data collection and member position methodology. Participants were asked to rate the other participants using the 3 axes of U/D, P/N, and F/B on a scale of 0 to 2. With 2 being maximum value of U, P, and F, and 0 representing the maximum values of D, N, and B (see Section 3.2 for more details). These values were filled into the Negotiation Log, e.g. in Table 4.4 Austro-Hungary rated both the participants playing England and France as being 2,2,2 with is a maximum score for U, P, and F meaning the participant representing England was very dominant in the negotiation, but also very positive and worked towards a collective outcome for both participants. Russia is also considered very dominant and working towards a collective outcome, but has a neutral attitude (neither positive or negative). The interaction with the participant playing Turkey shows them being somewhat submissive to the Austro-Hungarian participant with the 0 and 1 ratings for D resolving to 0.5, somewhat negative and actively working against collective outcomes.

Country	SYMLOG Rating
England	2,2,2
France	2,2,2
Russia	2,1,2
Turkey	0,1,0 and 1,0,0

Table 4.4: Austro-Hungary Mod-SYMLOG

The Mod-SYMLOG experiments took place on 2 different evenings on 21/01/2019 and 22/01/2019, with 2 games played on each day. On the first day 5 participants took part in game 1, and 4 for game 2. On the second day there were 7 players for game 3 and 6 for game 4. As with the pilot experiment, most of the participants were STEM PhD, MSc, or undergraduate students. However the participants were significantly less diverse than the pilot. All participants were male, between the ages of 18 and 32, and originated from the European continent.

4.3 Results

4.3.1 Phase 1: AI, Europa Universalis 4

Each game of EU4 started with a mixture of random seeding of rivals and some pre-scripted "historic friends and rivals" modifiers for opinions, allowing for some variation in AI decisions for diplomacy.

Once the relationships were extracted, standard SFDs and 3D-SFDs were extracted for each 5 year period between 1450 and 1500. These diagrams appear to be representative of a highly disordered group in a state of very limited mutual cooperation. The SFD can be seen in Figure 4.1 and 3D-SFD can in Figure 4.2.

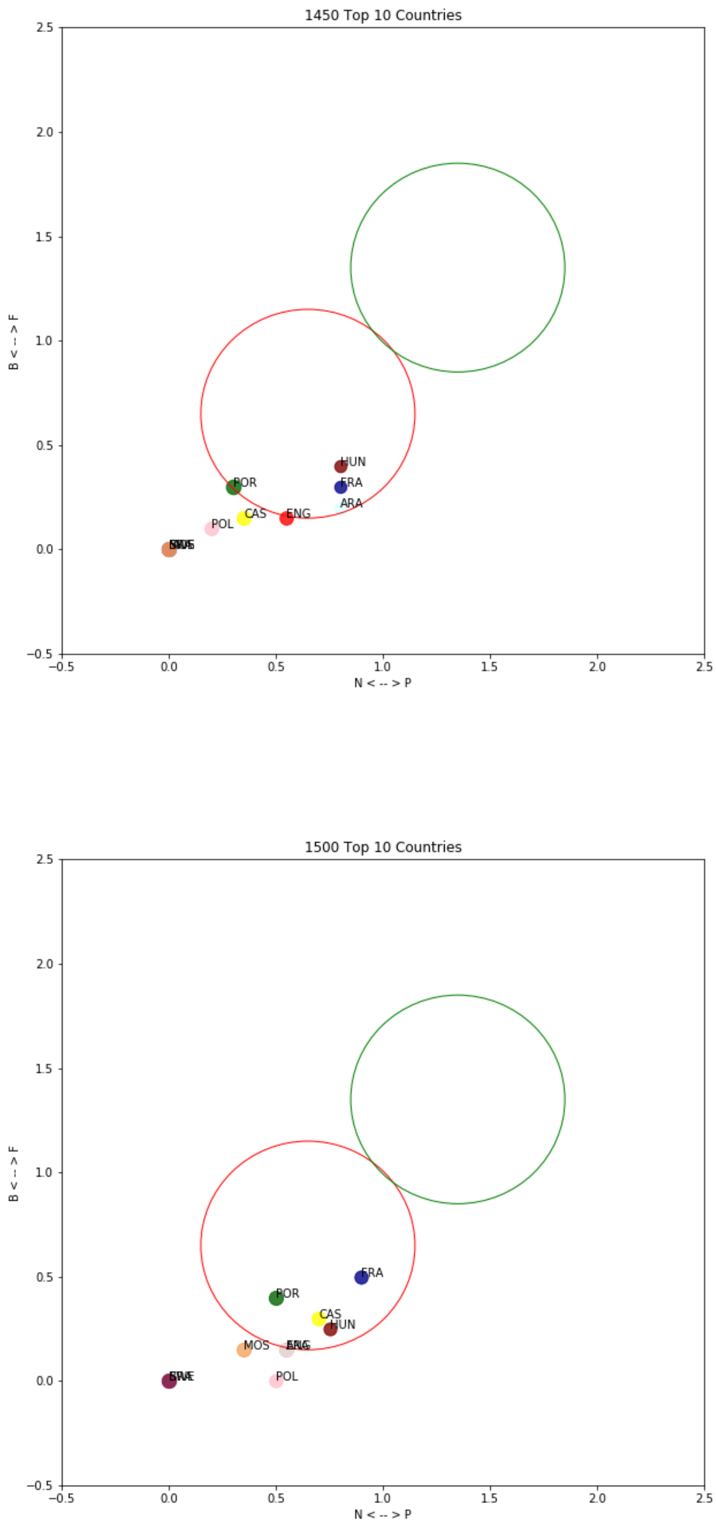


Figure 4.1: EU4 AI Years 1450, 1500 SFD

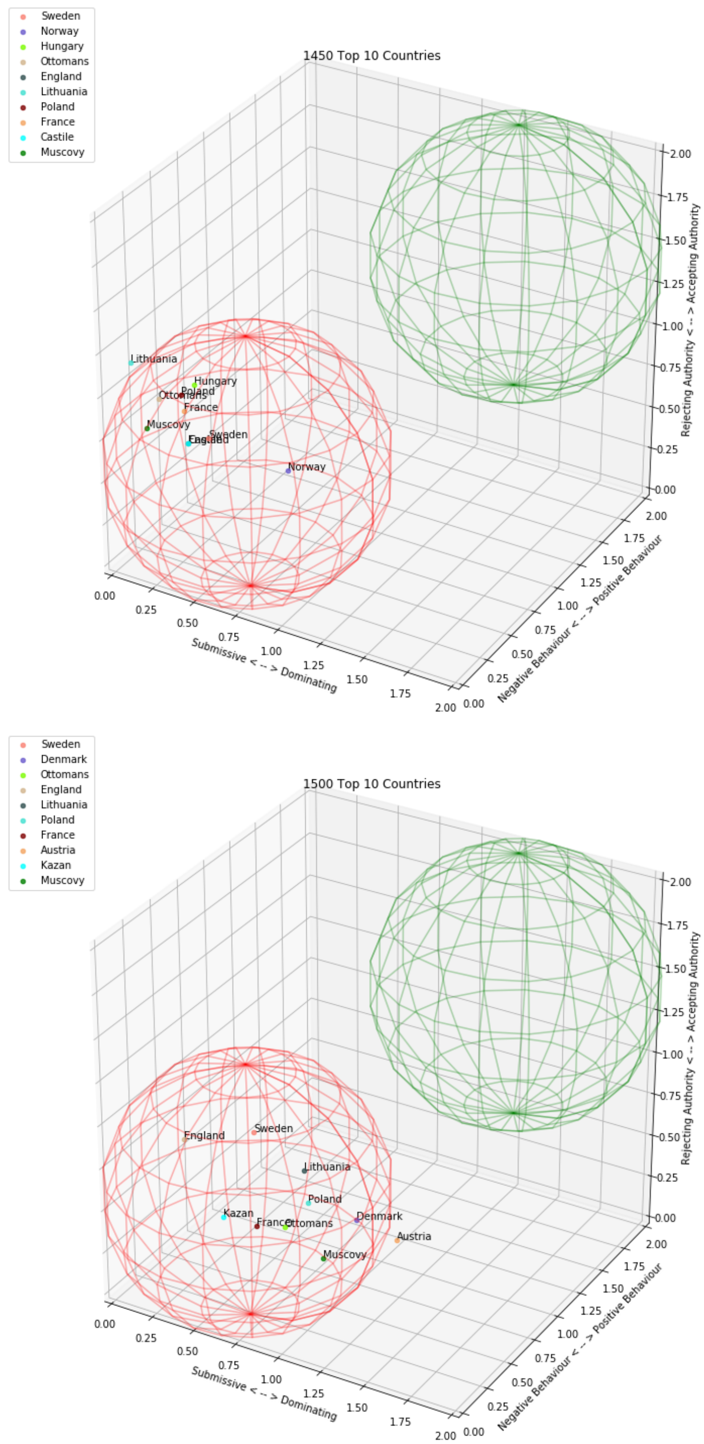


Figure 4.2: EU4 AI Years 1450, 1500 3D-SFD

For each of the games all AI countries fell into the non-cooperation areas of the SFD (see Figure 4.1 for an example from Game 3). The same non-cooperative state could also be seen in the 3D-SFD (See Figure 4.2). Node diagrams displayed the "allied" and "rival" statuses representing cooperation and defection respectively. These diagrams were generated for the 10 most powerful countries in the game (defined by having the greatest number of provinces owned in game) in the years 1450 and 1500. One exception was made in the case of Ming AI player, which despite being the largest country at the start of the game, had no interaction with the other largest countries within the first 50 years of game play. The lack of interaction between Ming and other players is a game-play mechanic restriction representing the lack of communication between the Ming Empire and Western Europe (where the other largest countries are) during the 15th century CE.

Participants were asked to review all SFD, 3D-SFD, and node diagrams for the 4 EU4 games and make assessments over what had happened in the previous 50 in-game years. When asked which scenario they wished to continue playing, all participants chose game 3, therefore the results from game 3 (with the AI set to Very Hard difficulty) will be used throughout this section.

The node diagrams for Game 3 (see Figure 4.3 for details) showed the following:

1450 Negative interactions (Rival) between Castile (CAS) and England (ENG) towards France (FRA), and between Poland (POL) and Muscovy (MOS).

FRA was recorded with alliances status (positive interactions) with Hungary (HUN).

1500 Rival status still existed between ENG and FRA. New alliances were recorded between Portugal (POR), CAS and ENG, and FRA towards Aragon (ARA). FRA has lost the Allied status with HUN, and HUN was now Allied to MOS. CAS was no longer in a Rival status with FRA, but in an Allied status.

When presented to the participants they correctly deduced the following events in the past 50 in-game years:

1. HUN or FRA had been in a war and had been forced to break their Allied status.

2. ENG entered a Rival status with CAS, which encouraged FRA and CAS to cooperate and achieve Allied Status.

3. ARA had Allied FRA to protect it from ENG and CAS.

Participants were then asked “If you were England, what would your next moves be?”. All 4 responded with very similar statements which directed an attack on CAS, supported by POR, with the idea that POR would request CAS to assist, while ARA would request FRA to help protect themselves. This would lead to FRA and CAS breaking their Allied status.

2 of the participants asked for more detailed node diagrams showing every active country in Europe. None asked for more comprehensive SDF or 3D-SDF diagrams (not included as they map 50 AI player relations). When asked

why they wanted more detail, both responded that the more complex SDF and 3D-SDF diagrams would provide additional information which would be useful as they were aware of how disunited the AI were at this point in the game due to the original diagrams.

All participants felt that they had enough information from the node diagrams to successfully plan the next few decades of play. This shows the ability for experienced EU4 players to understand the historic behaviour of groups and individuals within them without the need for additional information. While it is possible that some of the relationships can be assumed by the players (e.g. FRA and ENG always rival each other) this experiment supports the hypothesis that node diagrams can provide enough information to allow for understanding of complex group behaviour both historically and as a predictive tool. This would provide great utility for teachers within a classroom to monitor and support groups of learners with limited direct interaction. (Additional output figures can be found in Appendix B).

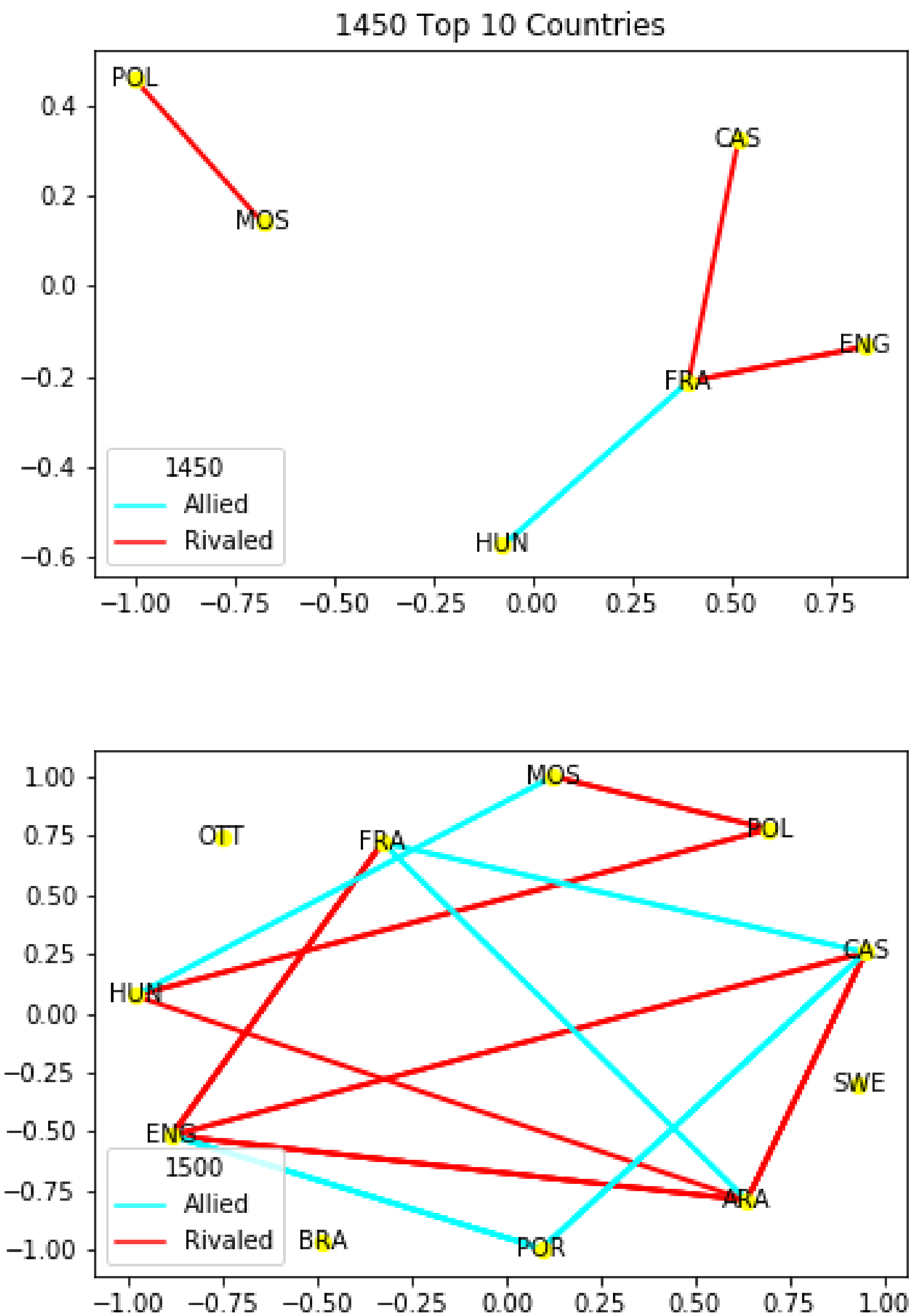


Figure 4.3: AI Node Diagram 1450, 1500

4.3.2 Phase 2: Human, Diplomacy Results

In phase 2 experiment 1 the Year 1 turn of SYMLOG Diplomacy was fairly cooperative, as participants avoided early conflict, working as a cooperative group, and agreed on the division of neutral territory. It is possible as most participants were STEM PhDs, they may have been aware that starting with cooperation and only defecting in response to a defection against you is a winning strategy[3]. Out of 13 recorded interactions between participants in Turn 1, 6 of the ratings were "UPF," 1 "PF," and 1 "F," meaning that 8/13 (61%) of the interactions were rated as positive. In turn 3 (Year 2 spring), 17 interactions were recorded of which 9 (53%) were negative. The position of each participant was calculated for each turn, based on the average rating received from all participants that recorded an interaction rating. For example, in Turn 1, England received a rating of "DPB" (quiet contentment) from Russia and "UPF" from Austria. The U and D values cancel each other out (i.e. neutral), as does the F and B values. This leaves England with an overall rating for turn 1 of P.

Once the results had been plotted, the participants were interviewed and asked if they felt that the SFDs accurately represented the group playing the game. Out of the 5 participants, 4 responded stating that the SFDs agreed with their own assessment of the group dynamics.

Figure 4.4 shows a sample of 2 SFDs from Turns 1 and 3, and Figure 4.5 shows the same turns using the 3D-SFD system. While all participants were in or near the effective teamwork sphere in Turn 1, the group is moving away from close cooperation by Turn 3, with Russia moving towards the disruptive area.

Interactions between participants were broadly defined as “Teamwork” and “Opposition” based on the location of these ratings when plotted within the classic SFD (Figure 2.1). Teamwork rating fell within the “PF,” “UPF,” “UF,” “P,” “UNF,” “UP,” and “F” ranges, while Opposition ratings where “BD,” “DB,” “DN,” “DNB,” “DPB,” “N,” and “NB”. In Figure 4.6 the direction of opinion is noted by an arrow, for example the blue arrow in Turn 5 pointing from Turkey (T) to France (F) (Figure 4.6) signifies that Turkey believed that France was being cooperative. These diagrams provide additional insight into how the group was interacting. We can see that Russia (R) and Austria (A), are cooperating from early in the game. Russia, who was cooperating with Germany (G) in Turn 2, moves to actively opposing Germany by Turn 5 thereby supporting Austria. This shift in diplomatic statues is copied by Italy forming a cooperative sub-group in opposition to a 2nd sub-group of Germany, England, and France. Turkey manages to position itself before both of these sub-groups as a mediator, with both sub-groups seeing Turkey as cooperative. (Summarised log of experiment data can be found in Appendix C).

4.3.3 Mod-SYMLOG

In all 4 games, mod-SYMLOG recorded groups forming in cooperative and non-cooperative states. Similar patterns of behaviour were captured as from

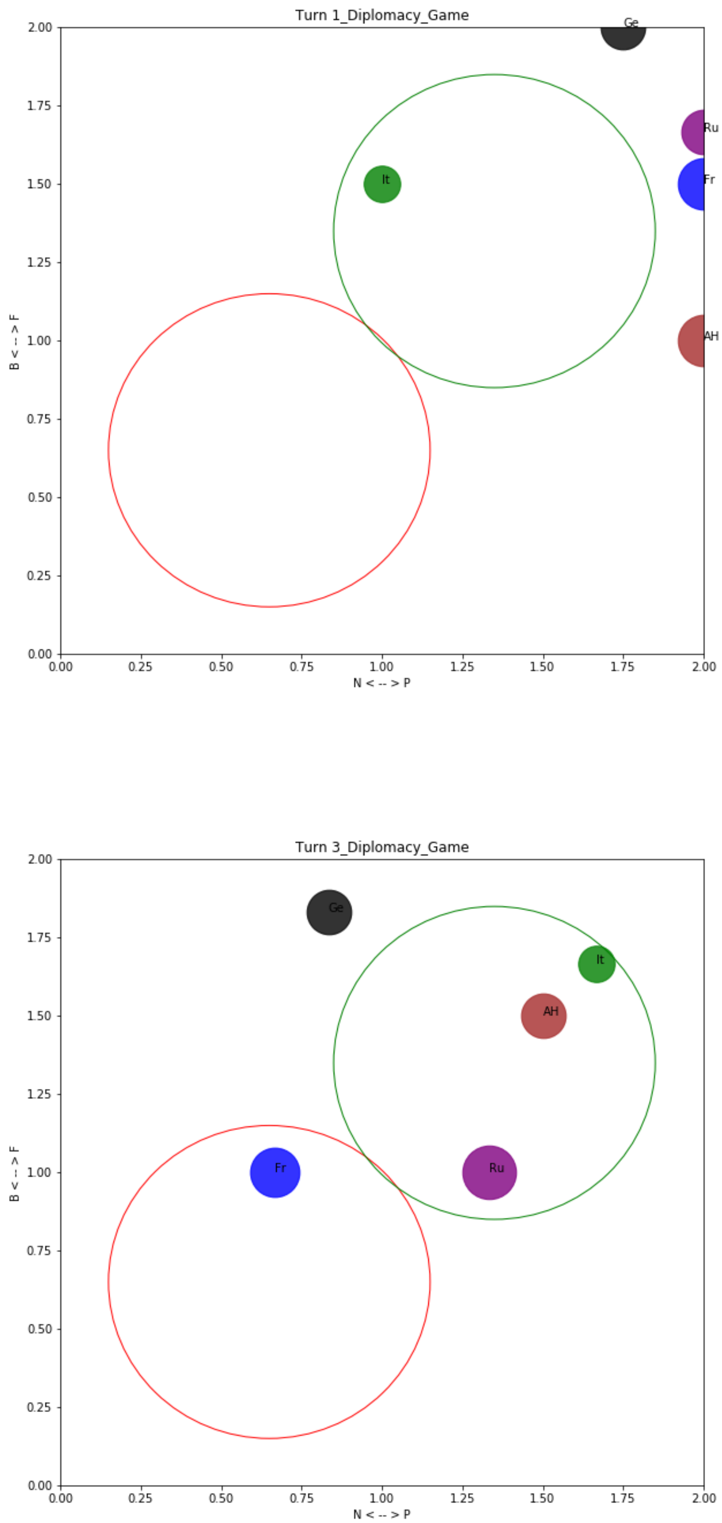


Figure 4.4: Human Diplomacy SYMLOG Turns 1 And 3

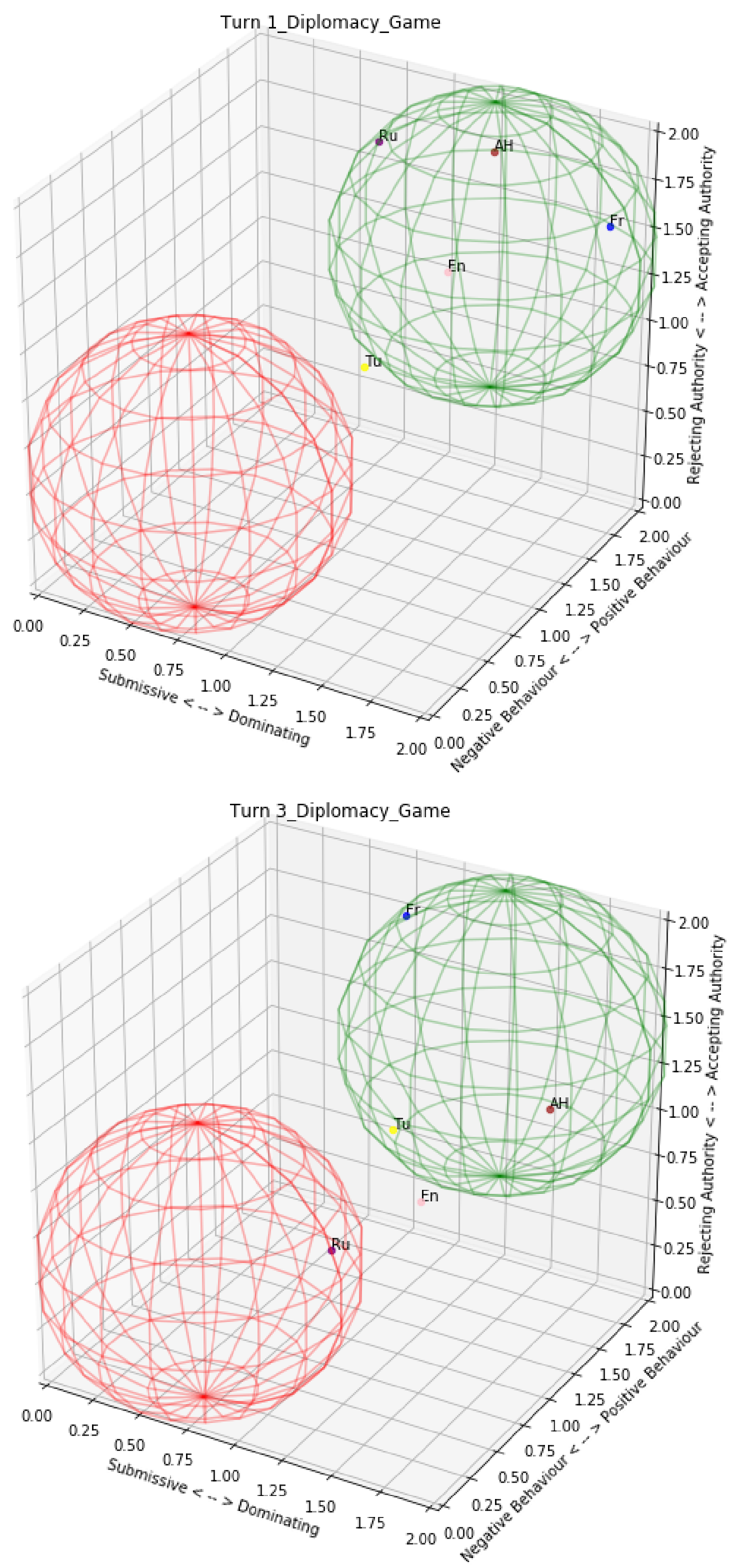


Figure 4.5: Human Diplomacy SYMLOG Turns 1 And 3 In 3D

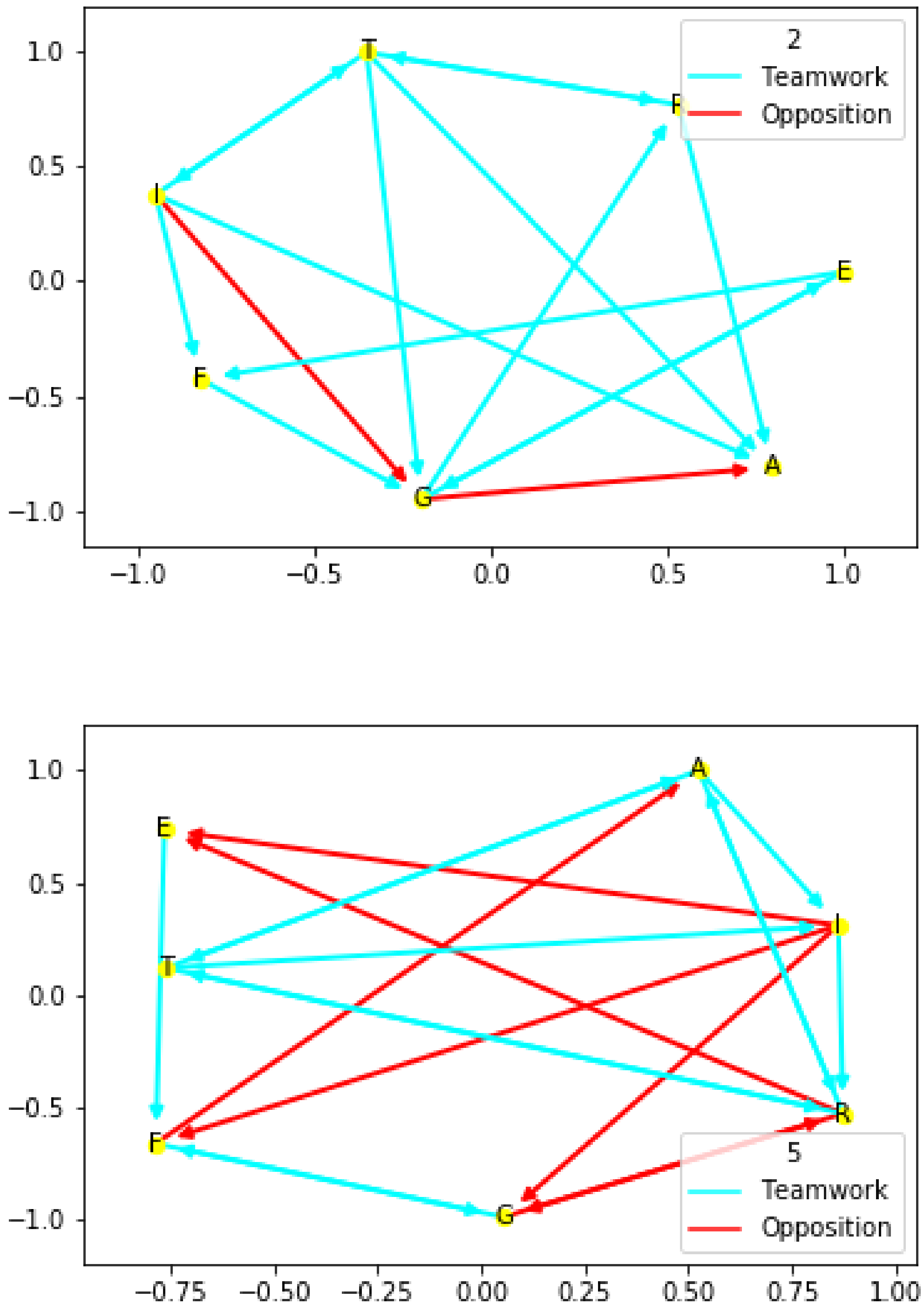
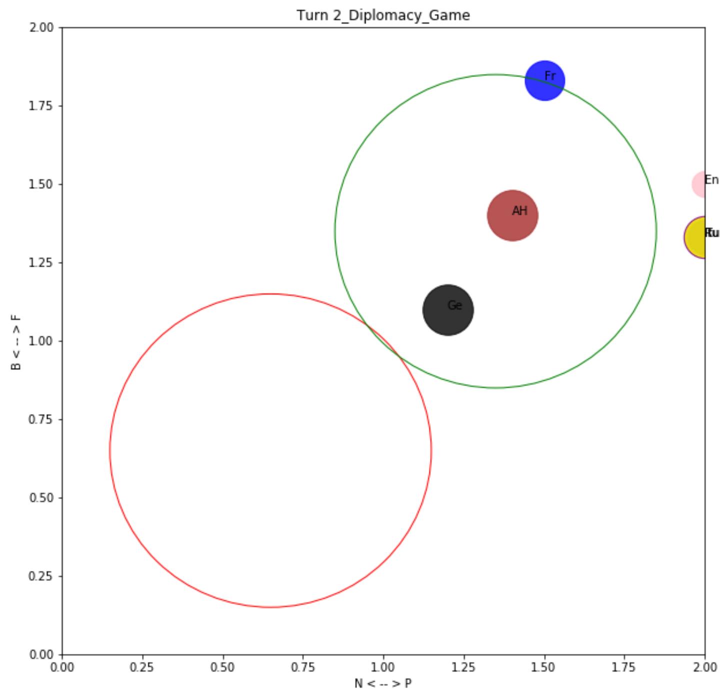


Figure 4.6: Human Node Diagrams Turns 2 And 5

phase 2 experiment 1 - the movement of the group from initial cooperation between all players to non-cooperation and/or formation of subgroups (see Figures 4.7 and 4.8 for an example from game 3).

The results from Game 3 provided indicators for sub-group formation. The node diagrams in Figures 4.9, 4.10 show negative interactions existing between Austria and Germany for turns 2 and 3 (see Table 4.6 and Table 4.7 for individual ratings). On turn 4 (Table 4.9 and Figure 4.11), France moves from a cooperative state with Austria in turn 3, to a non-cooperative state while maintaining a cooperative position with Germany (Figure 4.11). France has also been in a non-cooperative state with Italy, which maintained a cooperative state with Austria. This is the potential forming of two sub-groups where players seek cooperation against common non-cooperative players (France and Germany against Austria and Italy). The creation of these sub-groups transpires in turn 5, France and Germany are joined by England, while Austria and Italy are aligned with Russia. Turkey remains in a cooperative state with 2 to 3 members of each sub-group. Similar indicators of sub-group formation were seen in Games 1, 2, and 4. More detail on how individual participants viewed other group members in Turns 2 and 5 can be seen in Table 4.5 and diagrams in Figure 4.12. (Summarised log of experiment data can be found in Appendix D).



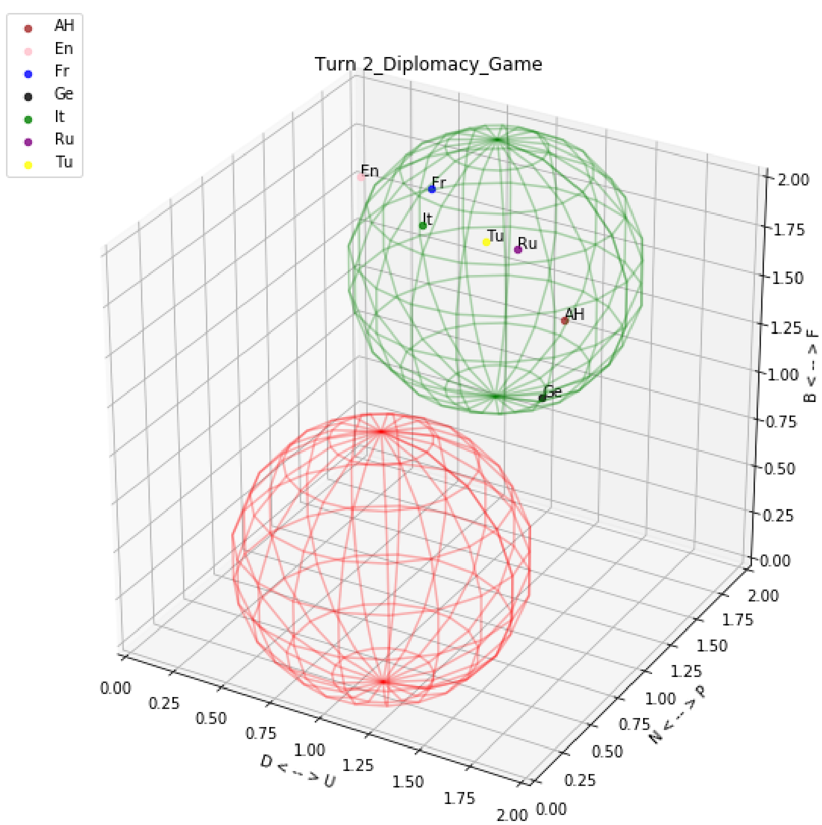


Figure 4.7: Human Diplomacy Game 3 Mod-SYMLOG Turn 2 In 2D and 3D

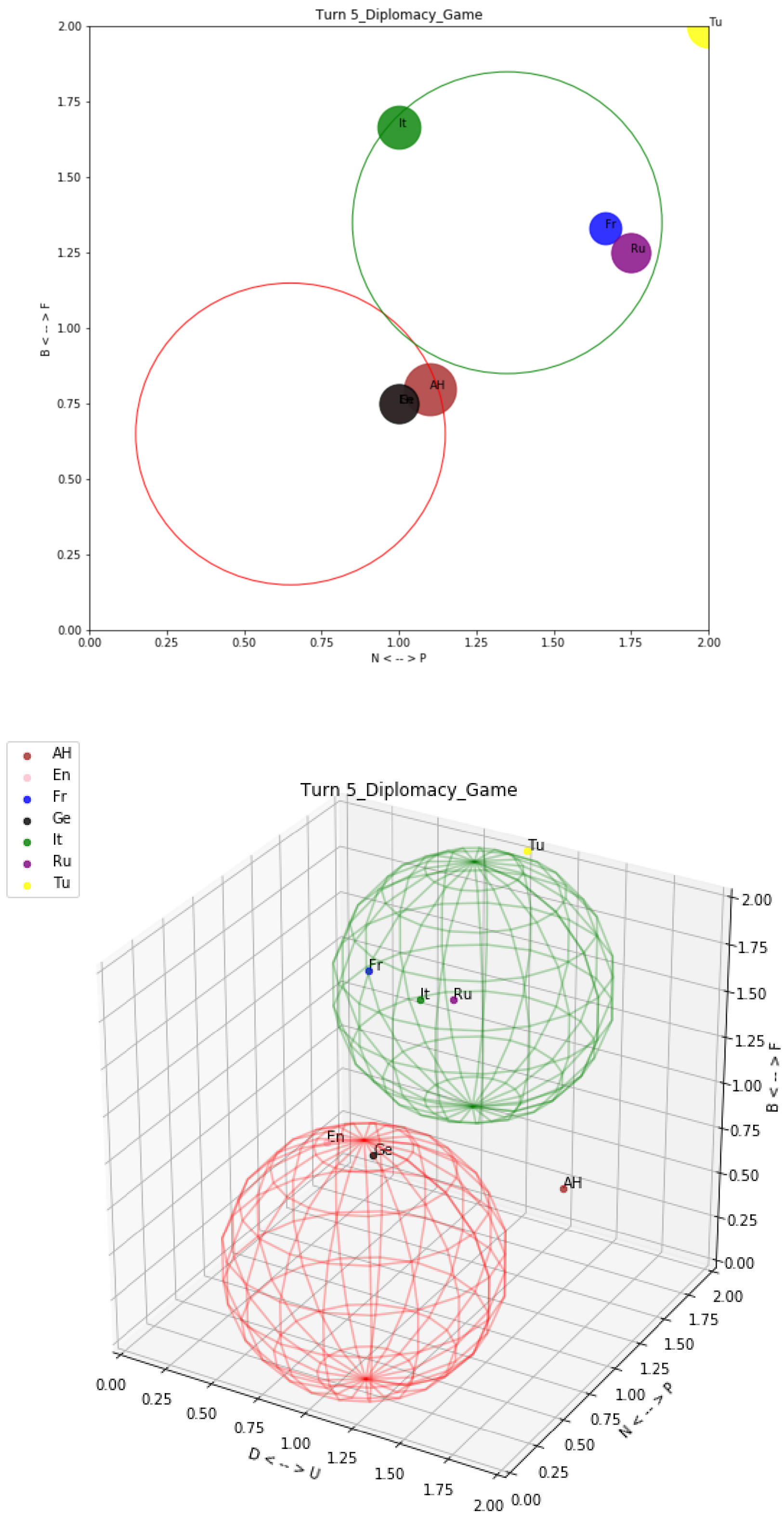


Figure 4.8: Human Diplomacy Game 3 Mod-SYMLOG Turn 5 In 2D and 3D

Player/Target	Turn	AH	EN	FR	GE	IT	RU	TU
AH	2					DP	DP	DP
EN	2			P, F	D, UF			
FR	2	U	DP		F	DP		
GE	2	DB	DP,F	D,DF			P,PF	
IT	2	UF		PF	UNB			PF
RU	2	PF			UPB,UPF			P
TU	2	UP,PF			PF,P	PF,P	P, UP	
AH	5					P	PF	PF
EN	5			D,F,P	P,D			
FR	5	UNB	DF		F	NF		
GE	5	UB	DP	DPF			B	
IT	5	PB	B	B	B		P	
RU	5	UPF	NB		NB			PF
TU	5	F, UNF				F	DPF	

Table 4.5: Game 3 Mod-SYMLOG Ratings Turns 2 And 5

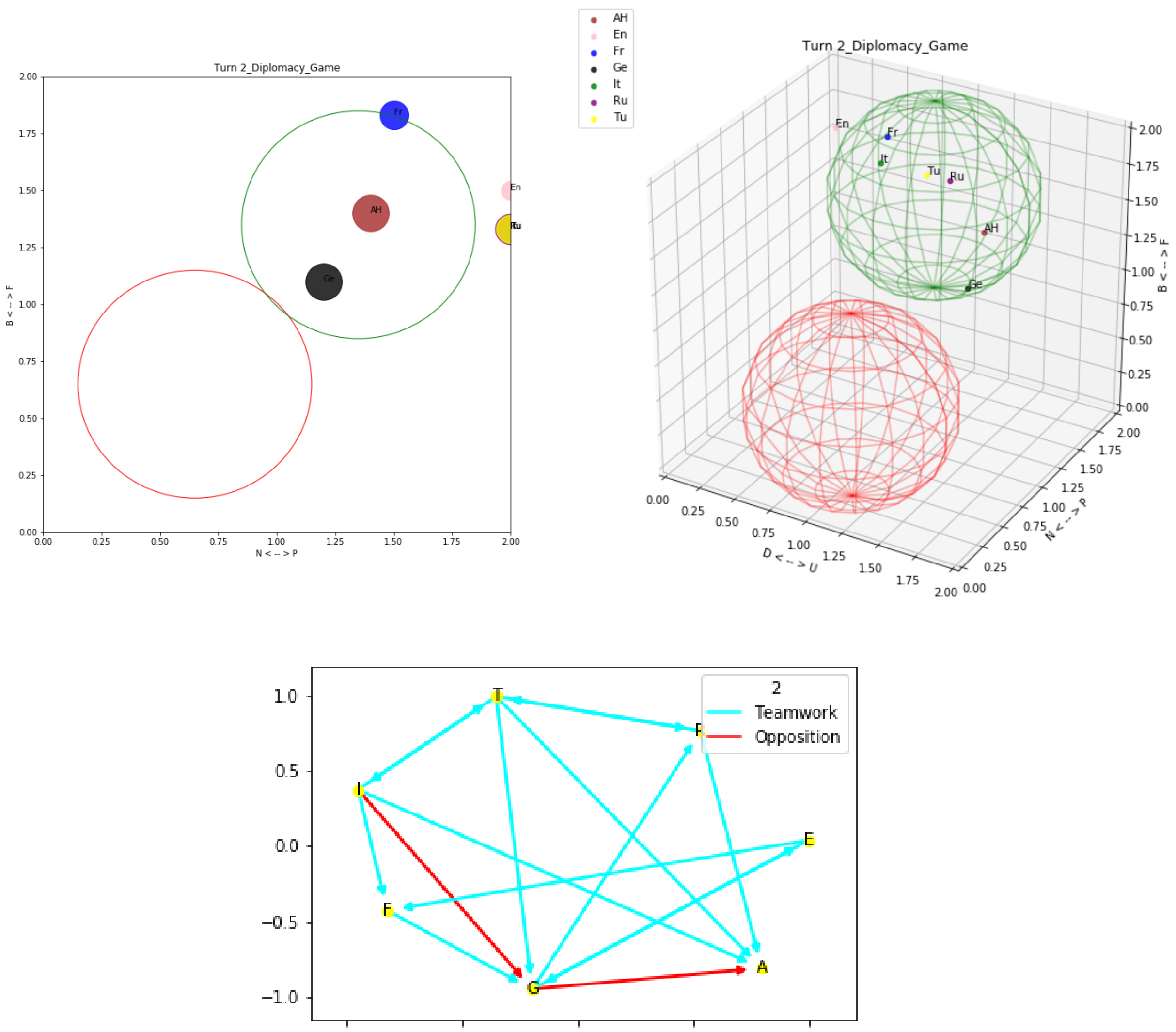


Figure 4.9: Human Diplomacy Game 3 Mod-SYMLOG Turn 2: 2D, 3D, And Node Diagram

Player/Target	Turn	AH	EN	FR	GE	IT	RU	TU
AH	2					DP	DP	DP
EN	2			P, F	D, UF			
FR	2	U	DP		F	DP		
GE	2	DB	DP,F	D,DF			P,PF	
IT	2	UF		PF	UNB			PF
RU	2	PF			UPB,UPF			P
TU	2	UP,PF			PF,P	PF,P	P, UP	

Table 4.6: Game 3 Mod-SYMLOG Ratings Turn 2

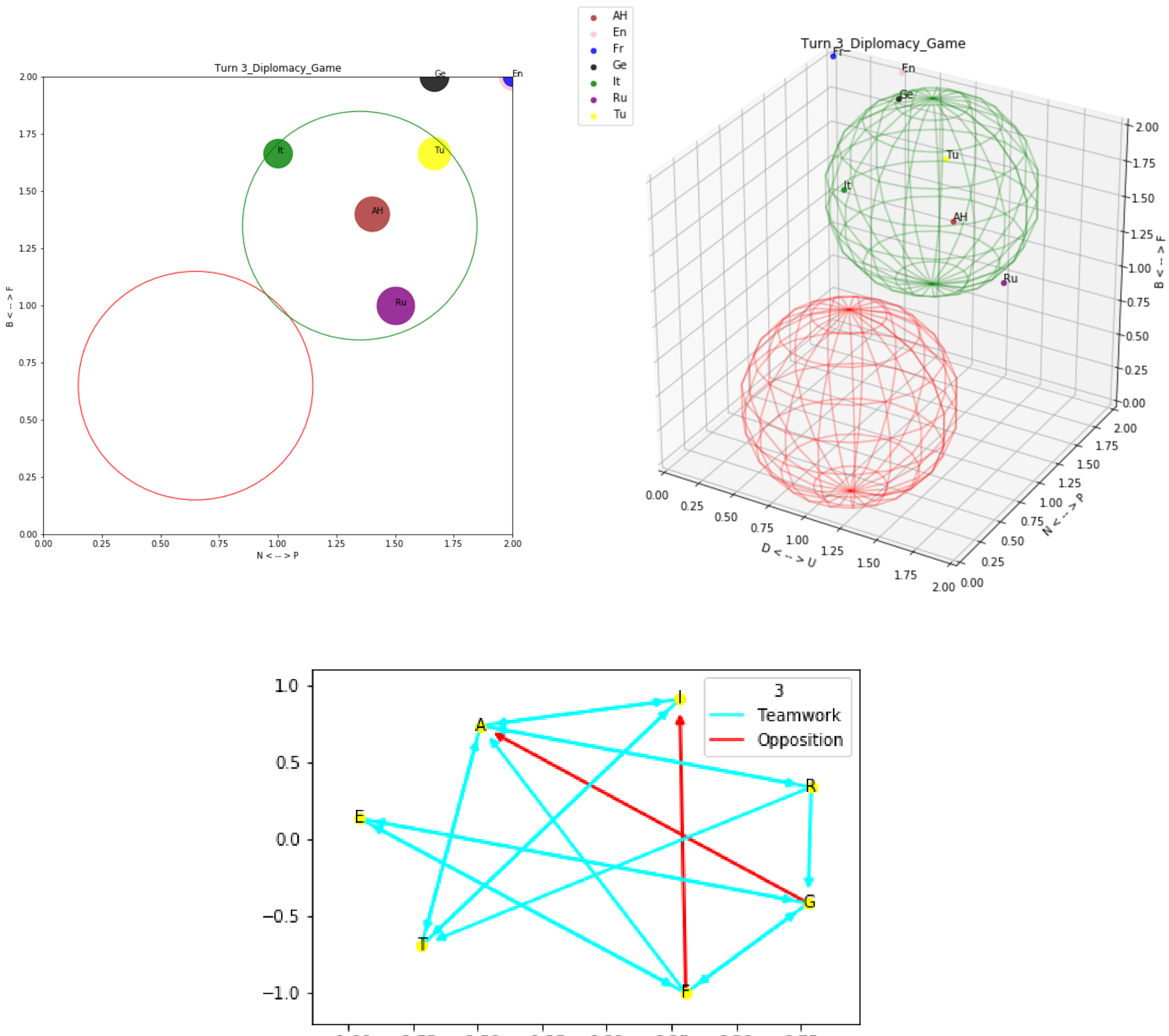


Figure 4.10: Human Diplomacy Game 3 Mod-SYMLOG Turn 3: 2D, 3D, And Node Diagram

Player/Target	Turn	AH	EN	FR	GE	IT	RU	TU
AH	3					PF	PF	PF
EN	3			P,DF	P,DF			
FR	3	P	PF		UF	DN		
GE	3	U,UNB	DP,PF	DP,DPF			UB	
IT	3	PF						F
RU	3	PF			DPF			P
TU	3	F				F		

Table 4.7: Game 3 Mod-SYMLOG Ratings Turn 3

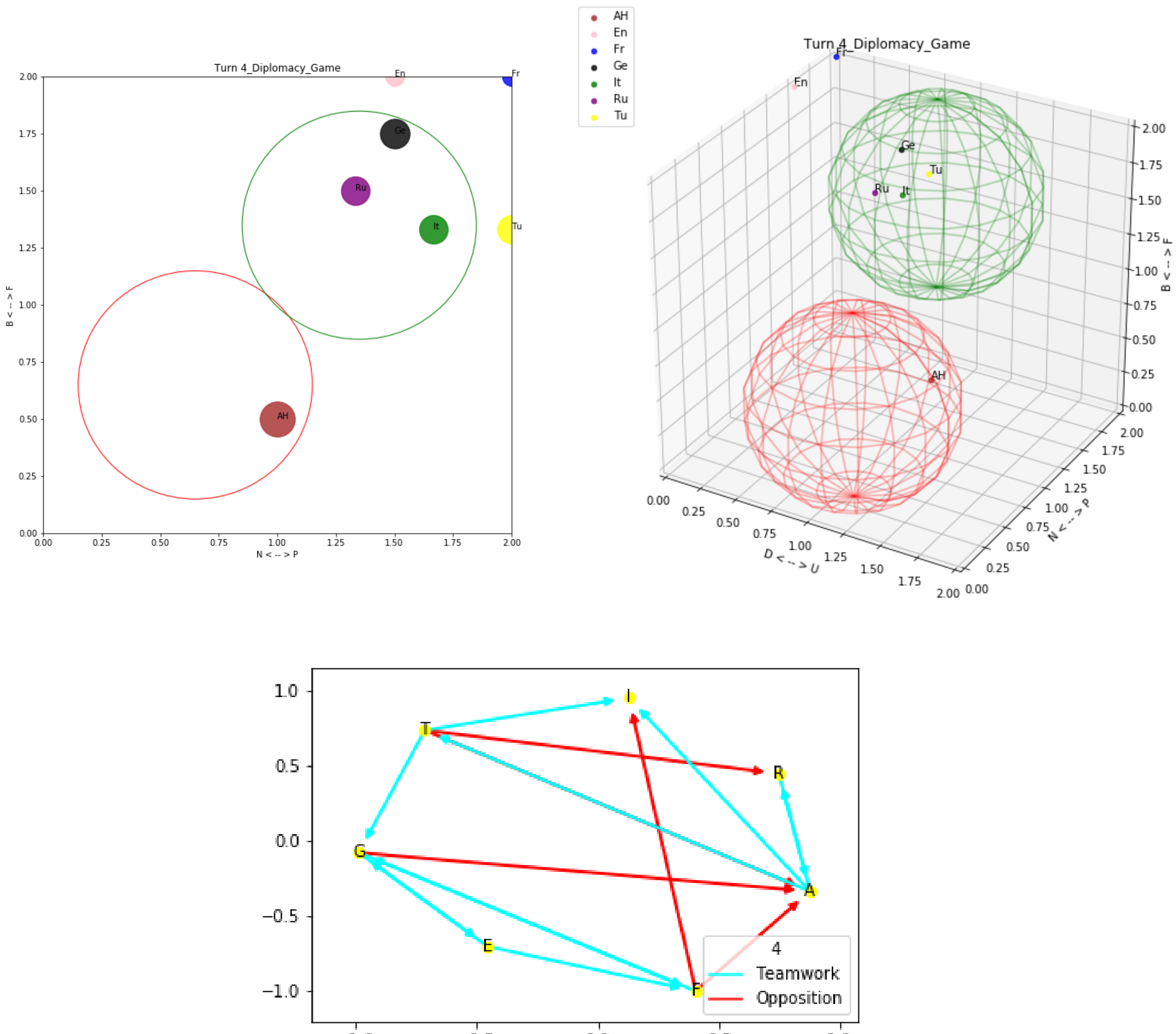


Figure 4.11: Human Diplomacy Game 3 Mod-SYMLOG Turn 4: 2D, 3D, And Node Diagram

Player/Target	Turn	AH	EN	FR	Ge	It	Ru	Tu
AH	4					PF	PF	DPF
En	4			P,D,F	P,D,F			
Fr	4	UNB	DF		UF	D		
Ge	4	DPB	DPF	DPF			DF	
IT	4						B	
Ru	4	UPF			DP			DP
Tu	4	NB			F	P	P, NB	UN,P

Table 4.8: Game 3 Mod-SYMLOG Ratings Turn 4

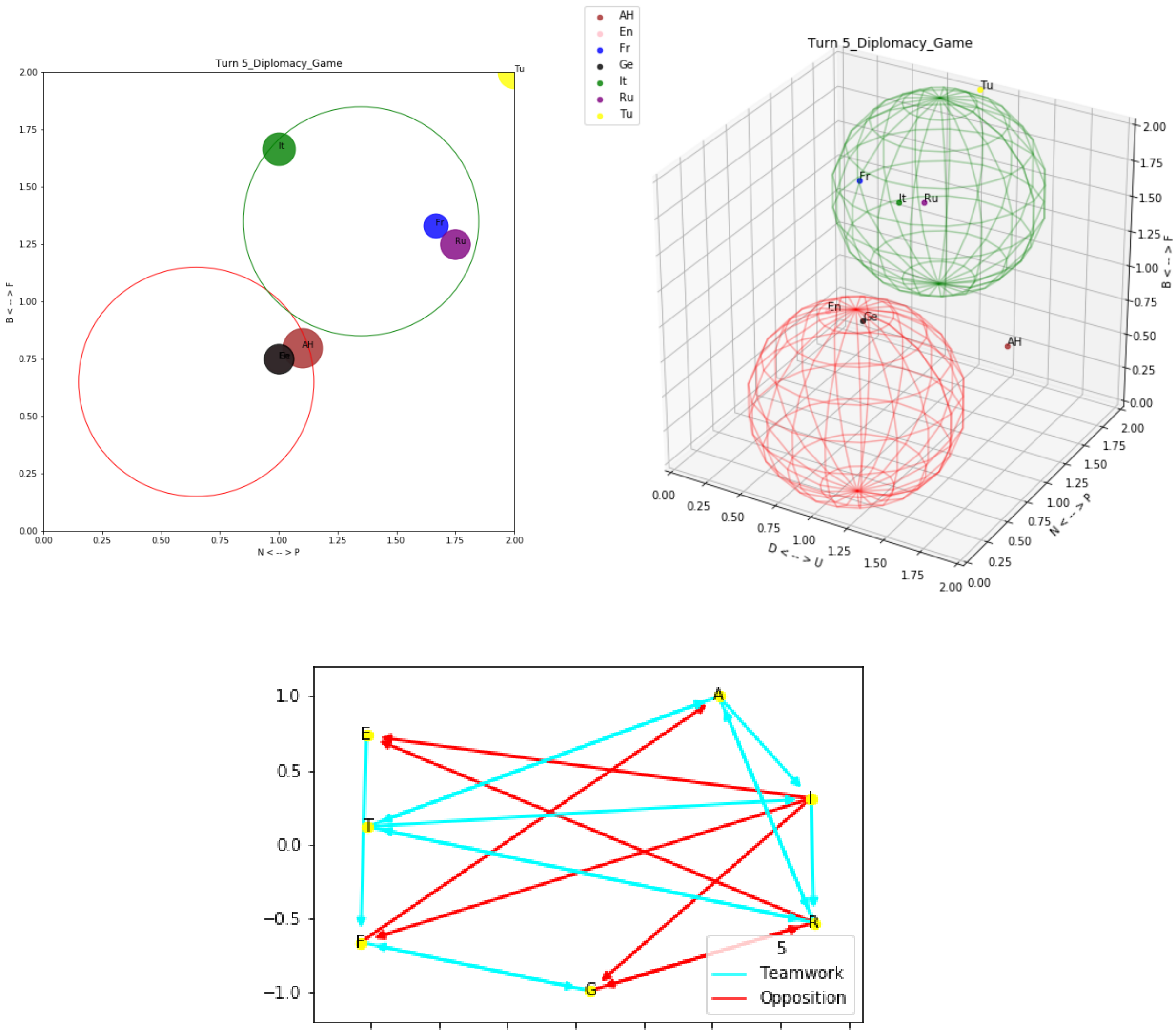


Figure 4.12: Human Diplomacy Game 3 Mod-SYMLOG Turn 5: 2D, 3D, And Node Diagram

Player/Target	Turn	AH	EN	FR	Ge	It	Ru	Tu
AH	5					P	PF	PF
EN	5			D,F,P	P,D			
Fr	5	UNB	DF		F	NF		
Ge	5	UB	DP	DPF			B	
IT	5	PB	B	B	B		P	
Ru	5	UPF	NB		NB			PF
Tu	5	F, UNF				F	DPF	

Table 4.9: Game 3 Mod-SYMLOG Ratings Turn 5

4.4 Summary

4.4.1 Phase 1: AI, Europa Universalis 4

Phase 1 showed the high utility of the 3D-SFD and SYMLOG Node Diagrams for interpretation of group states and the levels of cooperation/non-cooperation between members. Participants were also able to develop intervention strategies without any direct contact with the game state (and thus the groups within the game). This is evidence that new 3D-SFD and SYMLOG node diagrams can be used by an external observer (e.g. a Teacher or AI monitoring system) to access a situation, make basic conclusions over history of the group, and develop intervention strategies.

4.4.2 Phase 2: Human, Diplomacy

Both sets of experiments in Phase 2 have shown the ability to capture the dynamics of group behaviour and how these interactions can be modelled.

Participants identified categorisations of types of interaction as the most difficult part of the pilot experiment. For example, players found it difficult to distinguish between “UPF,” “UF,” and “UNF” during the negotiation phase. Mod-SYMLOG provided an easy to use alternative, with players asking fewer questions about how to encode ratings than in the pilot.

There is some indication that it is also possible to extract some group hierarchy from the data. In turns 4 and 5 Austria and Germany either viewed their respective cooperative partners as equal or submissive, or their partners saw them as Dominant and Positive (see Table 4.5). For example, in Turn 5 France viewed Germany as “F”, while Germany viewed France as “DPF,” suggesting some hierarchy. This concurs with observations from the game, where Austria and Germany were in clear leadership positions. Further experimental work would be required to establish both the validity of these potential hierarchies in addition to mod-SYMLOG use as a framework to describe them.

Active monitoring of students within the classroom, analysed through mod-SYMLOG, could provide teachers with the ability to monitor levels of group cooperation/non-cooperation and intervene, when necessary, to prevent negative groups from becoming established throughout lessons.

4.4.3 Research Questions And Answers

This Chapter outlined the ability of the Group Module of the ICTS system to:

1. Can either Europa Universalis 4 or Diplomacy be used in order to test mod-SYMLOG?

   – Both EU4 and Diplomacy were shown to be a useful frameworks to test mod-SYMLOG, with preference for reliability and validity given to Diplomacy.

2. Can mod-SYMLOG capture the interactions between groups?

   – This was demonstrated in Phase 1 and 2. In Phase 1 with the capturing of the non-cooperative status of the whole group among AI players, and in Phase 2 with the human participants.

3. Can mod-SYMLOG capture the formation of sub-groups?

   – In Phase 2, the formation of 2 clear cooperative subgroups formed, who then acted in a non-cooperative way towards all members of the other group (See Figures 4.10, 4.11, and 4.12).

4. Used to make assumptions around the history of interactions within the group.

   – In Phase 1 all participants were able to make accurate assumptions of 50 years of group interactions (game-play) of the largest countries in EU4.

Chapter 5

Prototype Group Survey

Assessing the structure of groups and the performance of individuals within groups has been an issue with the learning outcomes and marking of the Group Project Modules at the University of Essex (CE101, CE292, and CE293). By introducing a self reporting mechanism using mod-SYMLOG it is the aim to present the group as a visual model for Group Supervisors to review how well individuals are performing and identify any issues that arise. The initial experiment included only the 1st year undergraduate group project (CE101), but was later expanded to include the 2nd year undergraduate group projects (CE292 and CE293). Ultimately the survey returned too low a response rate to answer any of the research questions and is presented here as work completed and the basis of a methodology for potential future experimentation or implementation.

5.1 Introduction

This Chapter describes a study to generate and test Group Models based on mod-SYMLOG[80]. The Group Model is intended to assist a teacher and later an AI in an educational environment.

Team Project Challenge modules are undergraduate modules in Computer Science and Electronic Engineering at the University of Essex. For example, CE101 is a 1st year undergraduate module which seeks to introduce students to working within a project team and understand team roles and team management[85].

For many students they would be working with different demographics compared to what they may have experienced in previous educational settings. The aim of the study was to identify and resolve conflict within these groups to prevent students becoming disaffected with university study (either specifically Essex or in general higher education)[10] and supporting a positive group environment to improve socio-emotional skills and track the relationship of group performance and academic outcome (see section 2.2.3 for details in the effects of negative group interaction).

5.1.1 Research Questions

1. Can mod-SYMLOG be used to track groups long term?

2. Are mod-SYMLOG diagrams (SFD, 3D-SFD, and node diagrams) useful to group supervisors to monitor groups?

3. Can mod-SYMLOG diagrams be used to predict grades?
4. Can mod-SYMLOG diagrams be used to predict group breakdown?

These research questions can then be operationalised into hypotheses

1. Mod-SYMLOG4466 accurately records interactions between individuals when recorded over multiple separate interaction sessions.
2. Group supervisors rate mod-SYMLOG diagrams as being useful when monitoring groups are assigned to them.
3. There is a positive correlation between the number of positive interactions and the final grade achieved by groups.
4. Mod-SYMLOG provides one or more indicators of potential group break up.

5.2 Methodology

5.2.1 CE101

The basic information about the experiment was to be conveyed by the Module supervisor in the first lecture and students were to be reminded every other week during the lectures in the Autumn and Spring semesters 2019/2020. The first lecture included a slide on groups in education, a second slide on Modified SYMLOG, and a final slide on what they would need to do.

The CE101 module structure split the 392 students into 61 groups, consisting of between 4 and 6 students per group. Supported lab sessions of 2 hours duration were organised as part of the CE101 module with around half the groups allocated to having labs on even weeks (2, 4, 6, etc...), with the other groups having labs on odd (3, 5, 7, etc...) weeks. Students were asked to rate the interactions with other group members during these lab sessions. The ratings would be entered into a Moodle quiz. Each student within the group was listed with 3 Likert scales, one for each of the mod-SYMLOG ratings Dominant/Submissive (U/D) Positive/Negative(P/N), and work towards group goals/working against group goals (F/B) (see Figure 5.1 for example questionnaire). Each week these ratings would be extracted via an excel download, and 3 graphical representation of each group would be generated (SFD, 3D-SFD, and node diagrams). These representations were to be sent to the Group Supervisors for each group so they could monitor how the group was performing. The Group Supervisor would then be able to choose if they wanted to intervene and how to intervene. They would then provide feedback on how useful they found the diagrams.

5.2.2 CE292 And CE293

The 2nd year undergraduate CE292 and CE293 experiment commenced in the Spring semester 2019/2020. Due to the lectures no longer taking place, students were given an explanation of the research by the research team during lab sessions. Students were provided with a background in how SYMLOG

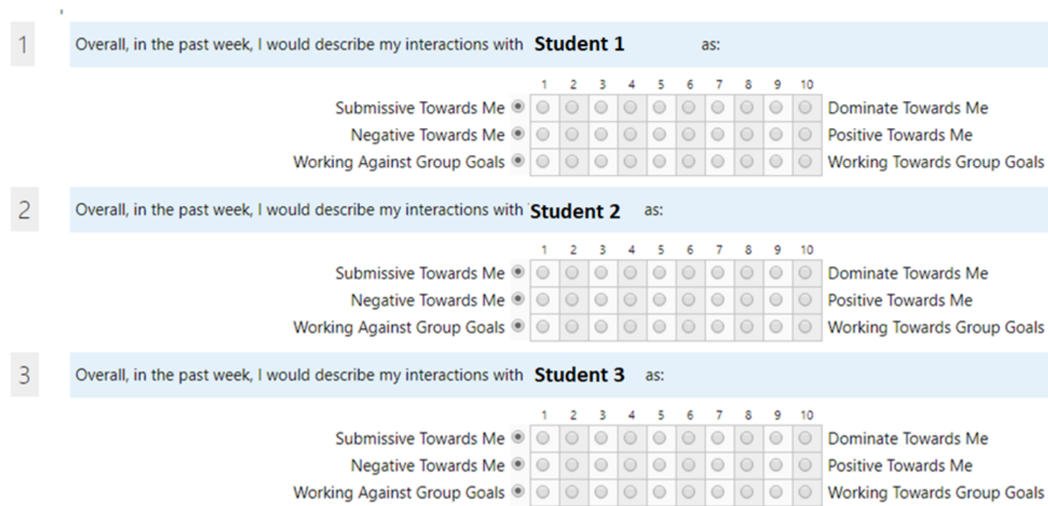


Figure 5.1: Likert Scales In Moodle For 1st And 2nd Year Undergraduate Group Project

represents group interactions, and the goal of the experiment to create a tool to assist teachers/lecturers during in-class group work. The students were allowed to ask questions about the research. The rest of the experiment followed the same methodology as the CE101 group, with participants filling in a survey every other week in order to provide visual representations to Group Supervisors.

5.3 Results

5.3.1 CE101

Of the 392 students enrolled on the undergraduate modules CE101 only 60 signed the consent form agreeing to take part in the study (15%) with 2 opting not to take part. Fewer than 100 responses were recorded in total, this represents less than 1.5% of a theoretical potential 7056 responses (18 formal laboratory sessions per group multiplied by total number of students). Of the 61 groups, 35 groups had at least 1 survey entry (43%), and 2 groups had more than 1 person responding (3%).

Group 45 provided the most detailed feedback with 3 out of 7 participants submitting survey data and all within the same 2 week period between laboratory sessions. Figure 5.2 shows the SFD, 3D-SFD, and node diagrams for the survey results found in Table 5.1. The data represents less than 50% of the entire group, however it displays a high level of group cooperation with all group members scoring above 8 for P/N and a minimum of 7.6 for F/B - with 10 being the highest rating for both categories. (All survey data from CE101 can be found in Appendix E).

Full name	P1 U/D	P1 P/N	P1 F/B	P2 U/D	P2 P/N	P2 F/B	P3 U/D	P3 P/N	P3 F/B	P4 U/D	P4 P/N	P4 F/B	P5 U/D	P5 P/N	P5 F/B	P6 U/D	P6 P/N	P6 F/B	P7 U/D	P7 P/N	P7 F/B
1	5	10	10	6	10	10	5	10	10	4	10	10	7	10	10	4	10	10	5	10	10
2	3	10	6	3	10	9	8	10	10	4	10	9	4	10	10	5	5	5	5	10	10
3	9	10	7	10	10	10	10	10	10	10	10	10	10	10	10	9	10	9	10	10	10

Table 5.1: Group 45 Raw Input

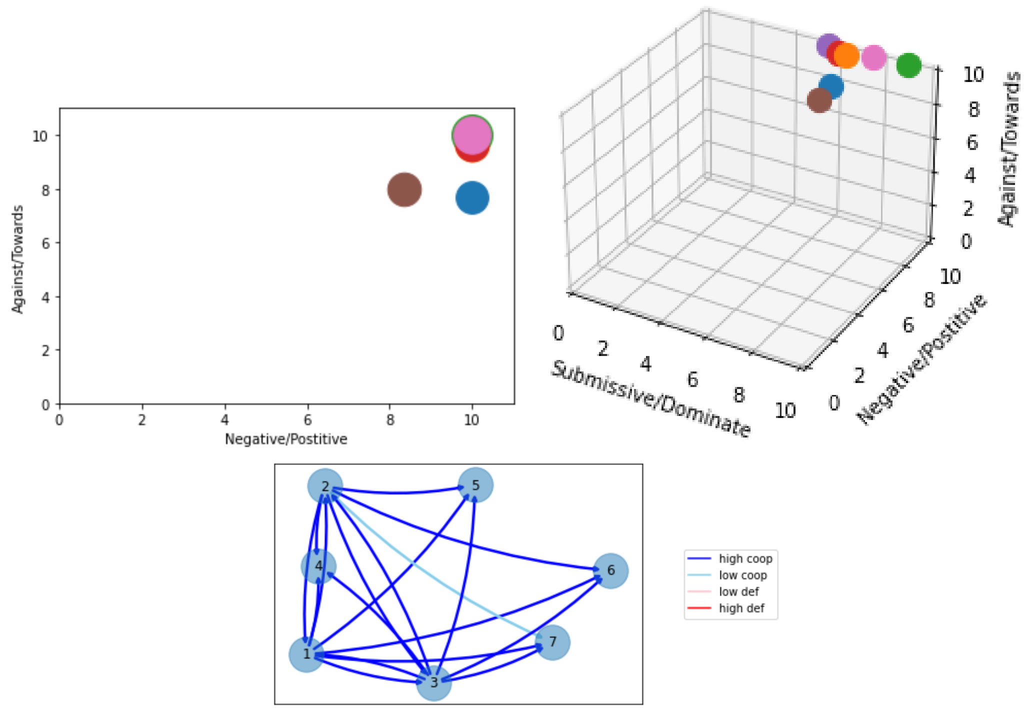


Figure 5.2: Group 45: 2D, 3D, And Node Diagram

5.3.2 CE292 And CE293

Of the 61 students enrolled in the second year undergraduate modules CE292 and CE293, 10 students signed the consent form with 1 student declining to partake. Of the 10 that consented to partake, 6 participants answered a single survey, representing 4 of the 11 groups, with 1 group having 3 responses.

5.3.3 Research Questions And Answers

1. Can mod-SYMLOG be used to track groups long term?

- This could not be answered in this experiment

2. Are mod-SYMLOG diagrams (SFD, 3D-SFD, and node diagrams) useful to group supervisors to monitor groups?

   - This could not answered in this experiment. This question is partially answered in Chapter 6 experiment 3.

3. Can mod-SYMLOG diagrams be used to predict grades?

   - This could not be answered in this experiment

4. Can mod-SYMLOG diagrams be used to predict group breakdown?

   - This could not be answered in this experiment

5.4 Summary

Several issues were encountered when setting up and running this experiment. A list of students and their groups was not provided until 18/10/19, 2 weeks after the start of term (3/10/19). Students were informed that there was an experiment in the 3rd week of November (around 11/11/19), by which point most of the useful information on group development would have already been lost. Students were surveyed by the research team during laboratory sessions and it was found that most students were unaware that there was anything that needed completing or that any experiment was taking place. The second year group projects (CE292, and CE293) were included in the experiment but by the time the information on the groups was collected there were only 1 or 2 labs left for the term so no useful data could be collected.

Recommendations

In a repeat of this experiment, it is recommended that:

1. Students are informed of the nature of the research at the outset by the lecturer
2. All supporting members of staff (e.g. in class support and Group Supervisors) are fully informed about the experiment
3. All supporting members of staff (e.g. in class support and Group Supervisors) are requested to remind students regularly to participate
4. Students are awarded a small amount of marks for the module for filling in the surveys, though not for taking part in the experiment.

Chapter 6

Predictive Model Testing And Teacher Interface (Mod-Snowdrift)

6.1 Introduction

Having defined mod-Snowdrift in Section 3.3 as a frame work to model group interactions 4 experimental questions were developed to understand its predictive capability when modelling group dynamics.

1. Which Prisoner's Dilemma strategy achieved the highest score in a game of mod-Snowdrift?
2. After how many turns do players stop engaging with Snowdrift strategies?
3. Does using the mod-SYMLOG node diagram allow more accurate ratings of group cooperation compared with only analysing final game

scores?

4. Can players accurately assess total contribution of groups from mod-SYMLOG diagrams alone compared with only analysing final game scores?

The first 2 questions were designed to test various Prisoner's Dilemma strategies within the mod-Snowdrift framework. The first with AI players to see if there are any differences between which strategies perform well and poorly in each framework. The second would then be used to assess the validity of the AI strategies when used against human players. Additionally this would provide an indication of when groups start to break down, allowing for a possible alert system for group leaders to assist in preventing group dissolution. The effectiveness of the mod-SYMLOG node diagrams were tested by the third and fourth questions, these questions examined how effective mod-SYMLOG node diagrams are as a tool to understand the levels of cooperation within groups.

These questions were operationalised as follows:

1. Prisoner's Dilemma strategy Cooperative will score higher than other Prisoner's Dilemma strategies in a game of mod-Snowdrift.

2. Players engaging with cooperative Prisoner's Dilemma strategies will continue to engage for more turns than when playing defecting Prisoner's Dilemma strategies.

3. When given the mod-SYMLOG node diagram players will more accurately rate group cooperation than when rating groups without the mod-SYMLOG node diagram.

4. Players with only the mod-SYMLOG diagram will be able to accurately estimate total scores for a group.

6.2 Methodology

6.2.1 Experiment 1: Prisoner's Dilemma strategies

Question: Which Prisoner's Dilemma strategies achieve the highest scores in a game of mod-Snowdrift?

Experiment 1 utilised the Axelrod python library [75] to provide a good benchmark for the Prisoner's Dilemma strategies. The library was then copied and modified for a mod-Snowdrift framework. Possible number of actions were increased from 2 to 4 (Cooperator, Light Cooperator, Light Defector, and Defector), and appropriate AI strategies were created or updated to be given these additional options. Scores were also changed to match the different payouts for the mod-Snowdrift model. Strategies for Prisoner's Dilemma selected are shown in Table 6.1

Strategy Name	Description
Cooperator	A player that always cooperates
Cooperator Spite	A player that starts off cooperating, then on turn 3 defects for the rest of the match
Defector	A player that always defects.
Random (0.2, 0.5, and 0.8)	A player that chooses randomly with a bias towards cooperation modifier of either 0.2, 0.5, 0.8.
Spiteful Tit for Tat	A player that will cooperate, but will defect permanently after the other player defects twice in a row.
Tit for 2 Tats	A player that mimics the last pair of moves from the other player, or returns previous action.
Tit for Tat	A player mirrors the actions of the other player.
Tricky Cooperator	A cooperator that will occasionally defect to improve payout.
Tricky Defector	A defector that will occasionally try to trick the other player into cooperating to improve payout.
Two Tits for Tat	A player that will defect twice each time the other player defects.
Tit for Tat Grim	A player that will mimic the lowest cooperation level, e.g. if player plays C, C, D, C, C then this strategy will play C, C, D, D, D.

Table 6.1: Standard Prisoner's Dilemma Strategies Selected

For the mod-Snowdrift competition 8 new strategies were added as shown in Table 6.2

Strategy Name	Description
Cooperator Light	A player that will always light cooperate
Defector Light	A player that will always light defect
Spiteful Tit for Tat Modified Snowdrift	A Tit for Tat player that will repeat the other players last move (including light cooperation and defection) but will permanently defect after the other player defects twice in a row
Tit for 2 Tats Modified Snowdrift	A player that mimics the last pair of actions (including light cooperation and defection) from the other player, or returns previous action.
Tit for Tat Modified Snowdrift	A player mirrors the actions (including light cooperation and defection) of the other player
Tricky Cooperator Light	A Light Cooperator that will occasionally defect to improve payout
Tricky Defector Light	A Light Defector that will occasionally try to trick the other player into cooperating to improve payout
Two Tits for Tat Modified Snowdrift	A player that will mirror any light cooperative, light defective , or defector action of the other player twice
Tit for Tat Grim Modified Snowdrift	A player that will mimic the lowest cooperation level, e.g. if player plays C, L, C, D, C then this strategy will play C, C, L, L, D

Table 6.2: Prisoner's Dilemma Modified Snowdrift Strategies Selected

The Prisoner's Dilemma Random strategy was modified to include the additional Light Cooperator and Light Defector options in the mod-Snowdrift game, allowing it to be capable of playing the full range of actions when appropriate. For a full list of the strategies used, see Table 6.4.

Each AI strategy played each other AI strategy for a match length of 50, with 100 repetitions in both Prisoner's Dilemma and mod-Snowdrift frame works. (A change log and code snippets can be found in Appendix F).

6.2.2 Experiment 2: Strategy Engagement

Question: At what point do players stop engaging with various mod-Snowdrift Strategies?

Experiment 2 was designed to examine how human players react to the various AI strategies while playing a game of mod-Snowdrift. It is hoped this would provide insights into when groups break down and assist in establishing some predictive models which could be used in a classroom or work environment. The experiment took place between 7/7/2020 and 14/7/2020 in which 118 participants were recruited via social media targeted at an academic audience, including the Twitter account "Academic Chatter" and various university forums. Participants were directed towards a website hosted on a home server and were unsupervised during the experiment. Due to the nature of the experiment set up (a website running on a home server) the demographics of the participants were not recorded.

8 strategies were selected from experiment 1: Cooperative (11/3); Light Cooperative (1); Tit for Tat (5/12); Light Defector (19); Defector (8/15); Random 0.5 (9/14); Cooperative Spite (13); and Spiteful Tit for Tat (3). Participants would not be made aware of which strategies would be included in the experiment, nor which one they would play during each game. The order of strategies was randomised for each player.

For each game, participants were asked to divide £10 between themselves and a central pot which would represent the effort put in by all groups members in a team project. This pot would be given a 10% "bonus" at the end

P1	P2	P1 Per. Pot	P2 Per. Pot	Cen. Pot	Bonus	P1 Total	P2 Total
10	10	0	0	20	2	11	11
7	10	3	0	17	1.7	12.35	9.35
3	10	7	0	13	1.3	14.15	7.15
0	10	10	0	10	1	15.5	5.5

P1 and P2 refer to Player 1 and Player 2 contribution
P1 Per. Pot is Player 1 Personal Pot
Cen. Pot is the Central Pot that both players have contributed to
Bonus is the 10% added to the pot
P1 and P2 Totals are the totals of the personal pot and their share of the central pot combined

Table 6.3: Example Returns For A Single Match In Experiment 2

of the game and divided between each players. This bonus represents the additional performance improvement that comes from teamwork[130]. Each game was cumulative, i.e. both players kept the total money they had won for each game. They could also see the last play by both themselves and the AI player.

Participants were given 4 options of what to contribute to the central pot, each corresponding to an action in mod-Snowdrift. £10 for Cooperator, £7 for Light Cooperator, £3 for Light Defector, and £0 for defect. The AI were given the same range of options but restricted depending on the strategy. The remainder of the money would go to their personal pot. Example returns can be found in Table 6.3.

Participants were informed they could stop playing with the AI player at any point, and either end the experiment or end the game with that strategy and start a new game with a new strategy.

6.2.3 Experiment 3 Mod-SYMLOG Node Diagrams

Question 3: Does using the mod-SYMLOG node diagram allow more accurate ratings of group cooperation?

Question 4: Can players accurately assess total contribution of groups from mod-SYMLOG diagrams alone?

The 3rd experiment aimed to examine if participants could estimate the cooperation of groups of AI players from mod-SYMLOG node diagrams. The experiment took place between 20/8/2020 to 27/8/202 where 122 participants took part in the study. These participants were targeted through the same social media as experiment 2 (see Section 6.2.2). Participants were directed towards a website hosted on a home server and were unsupervised during the experiment. Participants were asked to imagine themselves as a teacher marking a group project without having been able to view the groups working together before marking. Each group was created from 5 AI players playing a single round of mod-Snowdrift with each action having the same value as experiment 2. A total for each game was calculated as the sum of interactions between all players following the normal 2 player rules for payouts. Participants were provided a written tutorial explaining the diagrams with a worked example showing the calculations they would need to perform. Due to the nature of the experiment set up (a website running on a home server) the demographics of the participants were not recorded.

There were 3 experimental conditions: the first the participants were provided with only totals of the match; the second included a node diagram to show colour coded interactions and the total; and finally with only the node diagram.

The participants were provided with 6 levels of cooperation for the group, each with a numerical total range:

– High Cooperation - £185 to £200

– Good Cooperation - £155 to £184

– Moderate Cooperation - £100 to £154

– Low Cooperation - £45 to £99

– Very Low Cooperation - £15 to £44

– No Cooperation - £0 to £14

They were then provided with 3 additional rules:

– If a group has between 2 and 4 £0 contributions by any number of players (including 2 by the same player) a group cannot be rated higher than Moderate Cooperation

– If a group has between 5 and 9 £0 contributions by any number of players (including 5 by the same player) a group cannot be rated higher than Low Cooperation

– If a group has 10 or more £0 contributions by any number of players a group cannot be rated higher than Very Low Cooperation

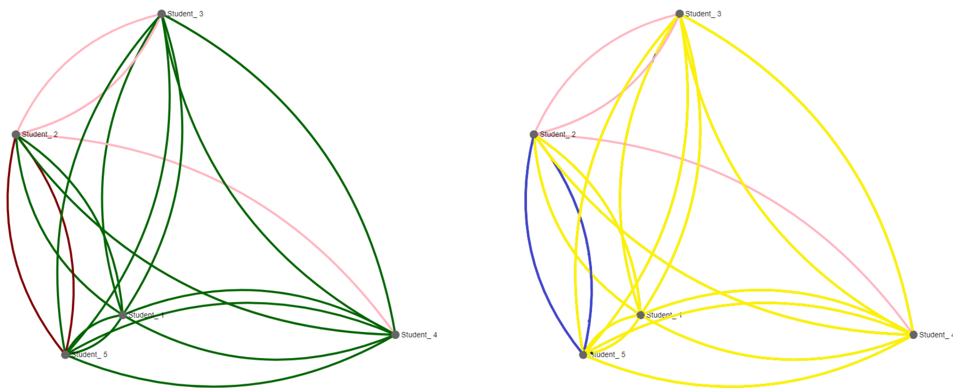


Figure 6.1: Examples Of Diagrams Provided To Participants In Experiment 3. Left Diagram Is Of The Standard Colour Scheme, The Right Is Of The Alternative Colour Scheme

For each condition 2 groups had ratings matching the totals for Cooperation level without any more modifiers and 3 had modifiers which placed the groups into lower Cooperation levels due to the number of £0 contributions. 2 different colour schemes were offered (See Figure 6.1). The original colour scheme of red/green is a potential issue as it is a common form of colourblindness, affecting 8% of men and 0.5% of women [26], therefore a scheme of yellow/purple was chosen as an alternative and the participants were given the option to switch between the 2 schemes.

6.3 Results

6.3.1 Experiment 1

Strategies that performed well in Prisoner's Dilemma tended towards more defection-based strategies, with Spiteful Tit for Tat, Tit for Tat Grim, and Two Tits for Tat ranking the highest, while more cooperative strategies were ranked lower (see Table 6.4). These findings are in line with other research into PD Strategies and suggests the framework being used for the experiment has a high reliability.

When reviewing the mod-Snowdrift results, it was found that the more cooperative strategies ranked higher, with only 2 of the original 13 strategies in Prisoner's Dilemma improving in rank. Table 6.4 shows the rank change of the strategies that appear in both the Prisoner's Dilemma and mod-Snowdrift experiments with Cooperator moving from 12th place to 3rd and Tricky Cooperator from 12th to 10th. Strategies that have a strong bias to defect had some of the largest drops in rank, for example Defector moves for 7th to 22nd and Cooperator Spite from 3th to 19th, both of which showing a drop of 15 places in the ranking. Strategies with more inbuilt cooperation for example Two Tits for Tat goes from 3rd to 7th moving down 4 places and Tit for Tat from 5th to 6th down 1 place. The new strategies which were created or modified for mod-Snowdrift also followed this pattern, with the more cooperative strategies ranking higher.

AI Strategy	Prisoner's Dilemma	Modified Snowdrift	Change
Cooperator	12	3	9
Cooperator Light	N/A	1	N/A
Cooperator Spite	4	19	-15
Defector	7	22	-15
Defector Light	N/A	21	N/A
Random: 0.2	8	16	-8
Random: 0.5	10	17	-7
Random: 0.8	11	15	-4
Spiteful Tit For Modified Snowdrift	N/A	8	N/A
Spiteful Tit For Tat	2	2	0
Tit For 2 Tats	6	5	1
Tit For 2 Tats Modified Snowdrift	N/A	12	N/A
Tit For Tat	5	6	-1
Tit for Tat Grim	1	4	-3
Tit for Tat Grim Snowdrift	N/A	9	N/A
Tit For Tat Modified Snowdrift	N/A	13	N/A
Tricky Cooperator	13	10	3
Tricky Cooperator Modified Snowdrift	N/A	14	N/A
Tricky Defector	9	18	-9
Tricky Defector Modified Snowdrift	N/A	20	N/A
Two Tits For Tat	3	7	-4
Two Tits For Tat Modified Snowdrift	N/A	11	N/A

Table 6.4: Experiment 1: Snowdrift Game AI Rankings All Strategies

6.3.2 Experiment 2

8 strategies were selected from Experiment 1, Cooperator; Light Cooperator; Tit for Tat; Light Defect; Defector; Random 0.5; Cooperator Spite; and Spiteful Tit for Tat. These were selected to represent the range of rankings used in Experiment 1, without participants needing to play all the strategies.

AI Strategy	Modal Value	Plays	2nd Modal Value	Plays	3rd Modal Value	Plays	4th Modal Value	Plays	5th Modal Value	Plays	Total Players
Cooperator Light	50	73	21	7	32	2	11	2	2	2	100
Cooperator	50	87	12	3	11	2	29	2	7	2	108
Tit for Tat	50	67	12	4	2	3	21	2	17	2	93
Random 0.5	50	42	11	4	36	2	14	2	8	2	71
Spiteful Tit for Tat	50	72	8	7	12	6	13	3	14	3	114
Cooperator Spite	50	15	7	11	12	10	6	10	9	8	78
Light Defector	50	87	6	3	7	3	4	2	9	2	114
Defector	4	14	5	12	50	12	3	9	7	8	77

Table 6.5: Experiment 2: Modal Value Of Human Plays With AI

Table 6.5 shows the top 5 modal values of plays against each strategy. For each strategy the modal value of plays that a human competitor continued engaging with an AI strategy (to a maximum of 50) is shown in the first column. The second column shows how many participants engaged with the AI for the modal value of plays. This continues through the 2nd, 3rd, 4th, and 5th most common plays with the final column being the total number of players that engaged with that strategy. This table covers the majority of plays for all of the strategies for the experiment, with 98.7% of the Defector plays, Cooperator Spite 94.9%, Cooperator 92.6%, Cooperator Light 90%, Defector Light 89.5%, Tit for Tat 89.2%, Tit for Tat Grim 87.7%, and Random 78.9 % of random plays.

For all of the strategies participants played the full 50 turns, apart from Defector in which only 12/77 participants (15.6%) played the full 50 turns. This makes 50 engagements the joint 2nd most frequent reoccurring value, with 5 turns of engagement having the same occurrence. The modal value for Defector is 4 turns (14/77 18%) but not by a statistically significant amount. For the rest of the strategies, Cooperator had the greater proportion of 50 turn plays (87/108 80.6%), followed by Defector Light (87/114 76.3%), Cooperator Light (73/100 73%), Tit for Tat Grim (72/114 63.2%), Tit for Tat (67/93 72%), Random (42/71 59.2%), and Cooperator Spite (15/78 19.2%). For the second most frequent number of engagements, participants played 12 turns with Cooperator (3/108 2.8%), Defector Light played 6 turns (3/114 2.6%), Cooperator Light played 21 turns (7/100 7%), Tit for Tat Grim played

8 turns (7/114 6.1%),Tit for Tat played 12 turns (4/93 4.3%), Random played 11 turns (4/71 5.6%), and Cooperator Spite played 7 turns (11/78 14.1%).

While Cooperator Spite also had 50 turns as the most common play, only 15/78 (19.2%) participants played the full 50 turns, with the majority of players (59/78 75.6%) playing less than 10 turns. Given that this strategy plays the first 3 turns as a Cooperator and then defects every turn after that, it is seen that that the majority of the players played for less than 7 defecting play turns. This is similar to the results for the Defector play turns where 62/77 (80.5%) participants stopped playing by turn 7.

	Mean	Mode	Number of Mode	Total Plays
Cooperator	43.93	50	87	108
Cooperator Light	41.84	50	88	100
Tit for Tat	40.94	50	89	93
Defector Light	40.92	50	90	114
Random	37.27	50	42	71
Tit for Tat Grim	35.82	50	92	114
Cooperator Spite	17.32	50	15	78
Defector	13.86	4	14	77

Table 6.6: Experiment 2: Strategy Ranked By Mean Plays

The number of mean plays is ranked in Table 6.6, which shows that the more cooperative strategies having more mean number of players per participant than the strong defecting strategies. Cooperator Spite and Defector are clear outliers, having a mean number of plays of 17.32 and 13.86, which is 21.96 and 18.25 fewer plays, less than half, than Tit for Tat Grim which is the third least played opponent. The remaining strategies range for mean plays is 8.11 from a high of 43.93 to a low of 35.82, which is less than half of the difference between Tit for Tat Grim and Cooperator Spite.

	Mean	Mode	Number of Mode	Total Plays
Cooperator	525.92	540.35	26	108
Cooperator Light	471.17	543.2	11	100
Defector Light	434.92	570.85	17	114
Tit for Tat	423.21	525.4	16	93
Random	411.31	542.65	6	71
Tit for Tat Grim	369.36	539	29	114
Cooperator Spite	90.35	223.4	11	78
Defector	50.21	5.5	18	77

Table 6.7: Experiment 2: Strategy Ranked By Winnings

When examining winnings for each strategy (see Table 6.7), there is a shift in the ranking of performance. Cooperator has the most highest mean winnings of any strategy, winning 54.75 more than the second best performing strategy, Cooperator Light, (525.92 to 471.17). Cooperator Light scores 36.25 more than Defector Light (471.17 - 434.92), which in turn scores 11.71 more than Tit for Tat (434.92 - 423.21). Random performs only slightly worse at 11.9 (423.21 - 411.31), and Tit for Tat Grim drops another 41.95 below Random (411.31 - 369.36). Cooperator Spite and Defector show large drop in mean winnings, with Cooperator Spite dropping 279.01 (369.36 - 90.35) and Defector a further 40.14 (90.35 - 50.21).

However the Modal winnings have a different but much closer grouping for second best performing strategy. With Light Defector scoring the highest modal score (570.85), which is 27.65 above Cooperator Light with 543.2. With only 4.2 separating the the modal scores of of Cooperator Light, Random 0.55 (543.2 - 542.65), Cooperator 2.3 (542.65 - 540.35), and Tit for

Tat Grim 1.35 (540.35 - 539). Standard Tit for Tat falls behind this second place grouping by 13.6 (539 - 525.4). Again Cooperator Spite and Defector perform worse with Cooperator Spite scoring 302 (525.4 - 223.4) less than Tit for Tat Grim, and Defector scoring a further 217.9 (223.4 - 5.5) less than Cooperator Spite.

Strategy A	Strategy B	mean(A)	mean(B)	diff	se	T	p-tukey	hedges
Cooperator	Defector	43.93	13.86	30.07	2.44	12.32	0.001	1.83
Cooperator	Cooperator Light	43.93	41.84	2.09	2.27	0.92	0.9	0.13
Cooperator	Defector Light	43.93	40.92	3	2.2	1.37	0.5	0.18
Cooperator	Random	43.93	37.27	6.66	2.5	2.66	0.654	0.41
Cooperator	Cooperator Spite	43.93	17.32	26.61	2.43	10.95	0.001	1.62
Cooperator	Tit for Tat	43.93	40.94	2.99	2.31	1.29	0.9	0.18
Cooperator	Tit for Tat Grim	43.93	35.82	8.1	2.2	3.69	0.654	0.49
Defector	Cooperator Light	13.86	41.84	-27.98	2.48	-11.28	0.001	-1.7
Defector	Defector Light	13.86	40.92	-27.06	2.41	-11.22	0.001	-1.65
Defector	Random	13.86	37.27	-23.41	2.69	-8.7	0.001	-1.42
Defector	Cooperator Spite	13.86	17.32	-3.46	2.63	-1.32	0.5	-0.21
Defector	Tit for Tat	13.86	40.94	-27.08	2.52	-10.74	0.001	-1.65
Defector	Tit for Tat Grim	13.86	35.82	-21.97	2.41	-9.1	0.001	-1.34
Cooperator Light	Defector Light	41.84	40.92	0.92	2.24	0.41	0.9	0.06
Cooperator Light	Random	41.84	37.27	4.57	2.54	1.8	0.5	0.28
Cooperator Light	Cooperator Spite	41.84	17.32	24.52	2.47	9.92	0.001	1.49
Cooperator Light	Tit for Tat	41.84	40.94	0.9	2.36	0.38	0.9	0.06
Cooperator Light	Tit for Tat Grim	41.84	35.82	6.02	2.24	2.68	0.654	0.37
Defector Light	Random	40.92	37.27	3.65	2.47	1.48	0.5	0.22
Defector Light	Cooperator Spite	40.92	17.32	23.6	2.4	9.82	0.001	1.44
Defector Light	Tit for Tat	40.92	40.94	-0.01	2.29	-0.01	0.9	0
Defector Light	Tit for Tat Grim	40.92	35.82	5.1	2.17	2.35	0.715	0.31
Random	Cooperator Spite	37.27	17.32	19.95	2.68	7.43	0.001	1.21
Random	Tit for Tat	37.27	40.94	-3.67	2.58	-1.42	0.5	-0.22
Random	Tit for Tat Grim	37.27	35.82	1.44	2.47	0.58	0.9	0.09
Cooperator Spite	Tit for Tat	17.32	40.94	-23.61	2.51	-9.4	0.001	-1.44
Cooperator Spite	Tit for Tat Grim	17.32	35.82	-18.5	2.4	-7.7	0.001	-1.13
Tit for Tat	Tit for Tat Grim	40.94	35.82	5.11	2.29	2.24	0.555	0.31

Table 6.8: Experiment 2: ANOVA Results Comparing Mean Number Of Plays of Human Vs AI Strategy

An ANOVA test for significance was run on the results for number of mean plays (Table 6.8), as this study is most interested in how human players interact with various AI strategies rather than which AI strategy performs best in terms of winning the largest financial pot. This is due to the experiment looking for prediction of group break up, not the most effective group combinations. 12 combinations show a significant difference in mean number of plays. Cooperator has a significantly higher number of mean plays (30.07) than Defector, Cooperator has 26.61 more mean plays than Cooperator Spite, Cooperator Light 24.52 more than Cooperator Spite, Defector Light 23.6 more than Cooperator Spite, and Random 19.95 more than Cooperator Spite. One can also view the differences between mean scores as performing in a given scenario, with Cooperator Spite attaining a lower number mean plays (18.5) than Tit for Tat Grim, Defector had 21.97 fewer mean plays than Tit for Tat Grim, Defector 23.41 fewer than Random, Cooperator Spite 23.61 fewer than Tit for Tat, Defector 27.06 fewer than Defector Light, Defector 27.08 fewer than Tit for Tat, and Defector 27.98 fewer than Cooperator Light.

Defector performs significantly worse against all the other strategies, apart from Cooperator Spite, which also performed significantly worse against every other strategy apart from Defector. There was no significant difference with any of the other strategy combinations. (A summarised version of participant responses can be found in Appendix G).

6.3.3 Experiment 3

Part	Mean Score/5	5/5	4/5	3/5	2/5	1/5	0/5	Total Players
1 Totals only	1.8	0	0	2	93	17	5	122
2 Diagram and Totals	2.6	0	30	24	24	12	6	100
3 Diagram only	2.55	7	23	22	15	19	9	98

Table 6.9: Experiment 3: Number Of Correct Answers Per Experimental Condition

Table 6.9 shows the number of correct answers. With totals only 2 people correctly categorised the 3 groups in which the totals matched their cooperation score (the other 2 having lower scores due to number of defecting plays), 93 identified 2 correctly, 17 only 1, and 5 participants did not identify any correctly. This gave a mean score for all participants of 1.8. None responses were removed. For the first experimental condition using both the totals and a diagram of the group interactions, 30 participants identified 4 groups correctly, 24 manged to identify 3 correctly, meaning 52 (or 52%) more participants were able to identify groups correctly compared to the totals only section. 24 identified 2 correctly and 6 did not identify any of the groups correctly. This gives a mean score of 2.6 correct. For the final group, using only diagrams 7 participants managed to identify all 5 groups correctly, 23 scored 4, 22 manged to identify 3, 15 achieved a score of 2, 19 were able to identify 1 group correctly and 9 failed to correctly rate any of the groups. This group had a mean score of 2.55, slightly lower than the combined condition, but not significantly. Both the graphical groups have $P<0.001$ when compared to the total only condition.

Question	V. Easy	Easy	S. Easy	N	S. Diff.	Diff.	V. Diff.	Not Sure
How easy did you find using totals ONLY for assessing group cooperation?	14	21	9	6	10	12	17	1
How easy did you find using node diagrams ONLY for assessing group cooperation?	15	13	19	9	24	16	5	1
How easy did you find using both totals and node diagrams for assessing group cooperation?	15	14	30	7	18	7	0	1

Table 6.10: Experiment 3: Questionnaire Responses On Difficulty Of Interpreting Experimental Conditions

Participants were asked to rate the ease of use of each condition when rating groups. 35/90 (38.89%) of participants found the total only condition either easy or very easy to use, while 28/102 (27.45%) found the diagrams only condition easy or very ease, and 29/92 (31.52%) answered the same for the combined totals and diagrams condition. Similarly, 29/90 (32.22%) of participants rated totals only as difficult or very difficult, 21/102 (20.59%) rated diagrams only as difficult or very difficult, and only 7/92 (7.60%) rated the combined condition the same, with 0 participants rating it very difficult. See Table 6.10 for the questions asked and the results.

Question	Yes	Yes, with option to change	No	Not Sure
Would you prefer only to see negative connections between students?	15	32	28	16

Table 6.11: Experiment 3: Would You Use This?

To investigate if participants wanted a different representation of the data, participants were asked if they would like to use the visualisations only showing the negative interactions between users (Table 6.11), with 15/91 (16.48%) saying they would use it, 32/91 (35.16%) saying they would use with the option to change to see all connections, 28/91 (30.77%) saying they would not like the negative interactions only, and 16/91 (17.58%) saying they were unsure.

Question	V. Useful	Useful	S. Useful	Not Useful	Would Not Use	Not Sure
If you were a teacher or a team leader, would you find these node diagrams useful for supporting your students/team?	21	17	28	5	3	17

Table 6.12: Experiment 3: Usefulness Of Diagrams

In the final question (Table 6.12), participants were asked if they found the diagrams useful or not, with 21/91 (23%) finding the graphics very useful, 17/91 (19%) useful, 38/91 (31%) finding it somewhat useful. 3/91 (3%) people would not use it, and 17/91 (19%) were not sure. (See Appendix I for individual participant responses to questionnaire).

The additional comments section on the questionnaire returned 21 comments from the 98 participants that completed all 3 parts of the experiment. These comments fall broadly into 3 broad categories. Complaints about the experimental set up, with comments including that the instructions were hard to follow (3/21 comments or 14%), suggested improvements or changes to the system (6/21 comments or 29%), and the rest generally supportive of the research aims. None of the participants commented on their responses to the questions in the questionnaire in their free comment section (Comments can be found in Appendix J).

6.4 Summary

1. Which Prisoner's Dilemma strategy achieved the highest score in a game of mod-Snowdrift?

    – Cooperative strategies were successful when competing against other AI strategies in the mod-Snowdrift game, with Cooperative Light ranking 1st, Spiteful Tit for Tat 2nd, Cooperator 3rd. Defecting strategies tended to be ranked lower with Tricky Defector Modified Snowdrift 20th, Defector Light in 21st, and Defector in last place (22nd).

2. After how many turns do players stop engaging with mod-Snowdrift strategies?

- Most of the strategies achieved a modal value of a full 50 turns, meaning that the majority of participants continued to engage with these strategies until they reached the turn limit. Defector achieved a modal value of 4, with 5 and 50 in joint second. Cooperator Spite, also scored a modal score of 50, but this represented a minority of players, the majority stopping engagement within 8 turns of the first defection. The mean number of turns played also show Cooperator Spite and Defector performing significantly worse than all the other strategies. However, as the demographics of the participants are not known, this result cannot be generalised.

3. Does using the mod-SYMLOG node diagram allow more accurate ratings of group cooperation compared with only analysing final game scores?

   - Participants were significantly more accurate rating group interaction scores with node diagrams than without.

4. Can players accurately assess total contribution of groups from mod-SYMLOG diagrams alone?

   - There was no significant difference between the groups with node diagrams only when compared to the diagrams and totals. Diagrams only still performed significantly better than only being provided a total score. However, it was unknown how much experience the participants had with game theory before conclusion of the experiment therefore it is difficult to generalise this result.

– Participants were asked if they

5. Additional comments

– If the experiment was to be repeated, a deeper qualitative analysis would be recommended with participants taking part in either individual or group feedback sessions after taking part in the experiment.

Chapter 7

Discussion And Potential Extensions To Research Within ICTS

7.1 Introduction

In this chapter a series of future research topics based on this thesis will be discussed, starting with examining extending the Group User Interface by using lighting to both stimulate student attention and the use of colours and darkness as a form of scaffolding or narrating a lesson, similar to theatre lighting. Possible extensions to Snowdrift with an intervention type action will be outlined. Additionally it includes a framework for dynamic reward allocation based on a combination of group leadership, Positive (P)/Negative (N), and Forward (F)/Backward (B) behaviour of group members from SYMLOG to assist in the creation of a more representative and detailed Group Model.

7.2 Lighting in Classrooms

7.2.1 An Introduction To The Study Of Light

To examine the use of light to convey information about a context or environment to a learner, this section will now review the history of psychology research into light and the results of classroom-based studies. The results from these studies will be used to direct the investigation of creating a Group Interface towards modifying the environment where light, or lack thereof, can be deployed to instruct an audience to assist narrating a lesson.

7.2.2 Colours

The colour of the lighting can also have an effect on subject responses to an environment [78][121][8][64], however the results for the effects of colour are less consistent than those for intensity of white light[64], with some researchers finding red to decrease error rate and produce the highest arousal factor[76] while others found this colour to be blue instead[68]. Responses to colour appear correlated to the cultural background of the subjects[64], or their gender[74].

This, however, might be down to cultural differences[64], as when colours are correlated to emotional responses within a population, a statistically significant correlation between mood and colour can be established[20]. Other studies have also shown a potential gender difference in the emotional interpenetration of lighting colours[74]. Berry found that while subjects cited a connection between colour and a perception of temperature, e.g. red as warm and blue as cool[8], there was no significant difference of temperature levels that subjects started to feel uncomfortable at when exposed to different coloured lights in a room (around 0.09°F or 0.162°C difference)[8].

7.2.3 Correlated Colour Temperature

The Institution of Lighting Engineers define Correlated Colour Temperature (CCT) as the temperature of the Planckian radiator perceived colour which most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions [120]. White light is measured on a range of 2,700Kelvin (K) to 6,500K, with 'warm' colours (reds and yellows) measuring towards 2,700K and 'cool' colours (blues) towards the 6,500K [74]. It should be noted that light with the same CCT measurement does not necessarily mean that they have the same colour spectrum [67] as it is the average of the red, blue, and green measurements within the light source that provide the CCT in Kelvin [25].

7.2.4 Classroom Studies With CCT

When examining the use of light as a medium to inform or stimulate learners within a classroom environment, this section will review 2 studies and the use of white light to stimulate learning. These studies are used as examples of how previous researchers have built early prototypes of group user interfaces, when investigating if it was possible to either replicate self-reported improvements in alertness of office workers or improve academic achievement. The use of light to achieve these ends is well founded in psychology research since at least the middle of the twentieth century. It has been shown that lighting has a direct effect on human psychology, physiology and behaviour[77][54][8], that this behaviour is predictable and, through lighting cues, alters the informational content of the local environment[83]. By utilising white light, sourced from either above a table, on the walls of a room, or a combination of both and adjusting intensity and level of diffusion, Hendrick et al showed not only a change in the subject's emotional reaction to a room but also their perception of the size and shape of the room[54]. Comparison of office workers using standard fluorescent lighting and daylight mimicking lighting showed that a lack of variation of light intensity throughout the day, i.e. not following the change of natural sunlight, can affect a person's sleeping pattern by limiting the production of the sleep hormone melatonin[77] as well as increased reporting of physical symptoms of fatigue, itching, among others[77].

Researchers have applied the results of workplace-based studies in the classroom and have found statistically significant effects on student performance based on the level of lighting [21][96]. Rautkylä et al examined the effects of CCT of white light on university students under lecture conditions. Rautkylä et al compared students self reported changes in alertness during lectures. The lectures took place over 2, 6 week periods, each consisting of

10 lectures each and were divided into 4 test conditions: Morning Spring Term (9:15-10:45), Afternoon Spring Term (12:15-13:45), Morning Autumn Term (8:15-9:45), and Afternoon Autumn Term (14:15-15:45). In the lecture theatre Rautkylä et al installed 4,000K (measured at 3,870K) and 17,000K (measured at 12,370K) florescent light sources in the lecture hall. Of the 4 test conditions only the Afternoon Autumn Term lecture showed a significantly lower drop in alertness levels of students, with the 17,000K bulbs showing effects similar to caffeine, but did not provide a significant additional increase in alertness levels when combined. However this may be due to to the use of blue shifted white light rather than red as a study by Sahin 2013 showed that exposure to red light increased alertness in the afternoon during the "post-lunch dip", whereas blue light did not, to a significant extent when measuring brainwave patterns on an EEG [101]. However blue light has been shown to increase alertness and reduce errors for officer workers when self-reporting [84].

Choi [21] studied 3 different lighting environments and the effects on fourth grade pupils (aged 10/11) compared to the standard lighting within the classroom. 2 groups of students were selected to be studied over a 2 week period. In the first week both sets of students had the standard fluorescent lighting, and in the second week the experimental group had their lighting changed to either 3,500K, 5,000K or 6,500K depending on the date of the experiment. Under these conditions each group performed a 120 second arithmetic test and their results compared. The control group showed little change over the period in test results (mean 62.31 pre-test, 64.91 post-test) while the experimental group showed an increase over their baseline results (mean 49.35 pre-test, 59.81 with 3,500K, 62.47 with 5,000K and 65.00 with 6,500K post-test). While the increase in the experimental group was greater, they achieved a mean test result, effectively the same as the control group over this period.

Given the experimental data, perhaps rather than looking at the office space for inspiration for enhancing learning through lighting, we could, instead turn to somewhere where lighting has become integral to the conveying of the narrative.

7.2.5 Classroom Interface - Theatre Inspired Darkness

House lights direct an audience. During a performance theatre house lights are often faded before the beginning of the performance leaving the audience in partial darkness. Both the darkness surrounding the audience and the speed at which the lights are dimmed provides the audience members with information about the emotional state of the scene that is about to be performed, slowly to reassure the audience and rapidly for a major emotional challenge [86]. This trend in creating a dark space in front of the stage before and during a performance appears to have started during the 18th Century when Giovanni Piranesi noted that this darkness, combined with background lighting on a stage, enhanced the illusion of reality within the audience members [33]. This effect has also been noted in the cinema [87]. The darkness in the auditorium has the dual effect of lighting use both on stage to enhance various emotional states with the use of coloured light without the bleeding effect of ambient light, and also to direct the audience attention to both the stage as a whole and areas of the stage that the director wishes them to focus on, removing possible distractions from other audience members and/or other sections of the stage [86].

ICTS theoretical model can use this darkness as a director for the Group Interface. By slowly reducing light within a classroom towards the end of a group activity learners will be informed that this section of the lesson is coming to an end and a new section will be beginning shortly. By leaving the first teacher as the sole focus of the light, similar to a theatre spotlight, learner attention will be directed towards the first teacher as they begin this new section. As with a play in a theatre, this can be seen as narrating a lesson with light and darkness.

7.2.6 Potential Issues

Low light levels or light that is too intense may cause temporary or permanent eye problems for some students. If the light level is set too low there is the possibility of eye strain when reading text on a screen or making notes, eye strain may also occur if light changes are too quick between low and high intensity. Intense changes in colour may also distract students if they are focused on completing tasks. There may also be an increase in fatigue and a decrease in academic performance caused by complex changes in lighting.

Installation of lighting rigs for dynamic systems in every classroom may be prohibitively expensive. However finding white light with a suitable CCT for the majority of situations may achieve a better cost/benefit result.

7.2.7 Proposed Research Questions: Light

1. Do different levels of white light affect group work?

2. Does the use of different combinations of colour lighting affect group academic performance?

3. Do different colour lighting combinations affect group social interaction?

4. Can the use of active theatre lighting improve student participation in an educational setting?

5. Does the use of darkness impair a students ability to record lessons?

7.3 Intervention Action

A new type of action called Intervention (I) could also be included. In classic Snowdrift games, players are either working towards a goal, or away from a goal. There is another possible I action, where a player, rather than actively pursuing to complete the goal, attempts to win over a Light Cooperation (LC)/Defection (D)/Light Defection (LD)/Hard Defection (HD) player. This

Intervention matrix is shown in Table 7.1. In Table 7.2 Intervention scores are placed within the normal payoff matrix. Each Intervention action has a score of -100 this is to represent the the Intervention player is using their action to persuade the LC/D/LD/HD player to perform more cooperative actions instead of working towards completion of the task. The other player has the same range of actions they have in a normal game in response to the I action. Intervention actions are high cost actions with no reward in that game term, but are designed to promote more cooperative behaviour in the future from a defecting opponent.

		Cooperate	Cooperate	Intervention	Defect	Defect
		Hard	Light		Light	Hard
Cooperate	Hard	R/R	RH/RL	I/HC	TH/SL	S/T
Cooperate	Light	RL/RH	RR/RR	I/LC	SS/TT	TL/SH
Intervention		HC/I	LC/I	X	LD/I	HD/I
Defect	Light	SL/TH	TT/SS	I/LD	PP/PP	PH/PL
Defect	Hard	T/S	SH/TL	I/HD	PL/PH	P/P

Table 7.1: Modified Snowdrift Intervention

		Cooperate	Cooperate	Intervention	Defect	Defect
		Hard	Light		Light	Hard
Cooperate	Hard	200/200	175/225	-100/0	150/250	100/300
Cooperate	Light	225/175	150/150	-100/25	125/175	100/200
Intervention		0/-100	25/-100	X	75/-100	100/-100
Defect	Light	250/150	175/125	-100/75	25/25	0/25
Defect	Hard	300/100	200/100	-100/-100	25/0	0/0

Table 7.2: Modified Snowdrift Scores

7.3.1 Proposed Research Questions: Intervention

1. Does an intervention type action exist or is it just a form of cooperation?
2. Does the intervention type action provide additional information that is useful for modelling and predicting group behaviour?
3. What cost should an intervention action have?
4. What payoff should the other player receive for responding to an intervention action?

7.4 Dynamic Costs/Reward Based on Leadership

Here is presented early work outlining possible dynamic cost/reward calculations based on effectiveness of leadership within a group. Leadership here is being defined as the ability to use social influence on others to achieve a common goal[18]. A strong leader or a leader within a group with high levels of cohesion would use less social influence to persuade others to achieve a goal than a weak leader or a group with low levels of social cohesion. Leadership in this model can be viewed either as a single leader within a group, and the effectiveness of their skill set, or by the overall unity of a group. The hypothesis is that groups with good leadership scores have a lower cost of action compared to low leadership scores, i.e. having a good leadership rating lowers threshold cost of action (inertia).

Description	Suggested Boundary	Additional Score
Extra Good	1.8	0.7
High Bound Good	1.5	1
Low Bound Good	1	0.5
High Bound Bad	0.5	-0.5

Table 7.3: Potential Group Effort/Reward Calculations Based On Leadership (Early Work)

Figures 7.1 and 7.2 show mod-SYMLOG inspired graphs showing cost to reward scenarios based on normal and low leadership scores for a group. The Y axis shows the Positive/Negative (P/N) score of a player, with 0 being full negative, 2 being full positive and 1 neutral. The X axis is the Forward/Backwards (F/B) scale of a player, where 2 is full forward, 1 neutral and 0 being full Backwards. The graphs have 4 colours for 4 types of reward bracket, dark green is a high reward, light green is a medium reward, yellow is low reward, and red is no reward for action. These reward brackets are not the same as payoffs but the amount of effort needed to gain access to higher group payouts. For example in figure 7.1 a high F/B score (>1.6) can provide access to a higher level reward with an P/N score of >0.5. Similarly in a low leadership group, even high scores of F/B and P/N (>1.7) only provide medium group payouts. These are based on personal observations and a general idea of scores rather than fixed numbers, and are being used for starting points for further research.

The calculations for the payout boundaries are based on group members actions within a social group not being binary/trinary, but a gradient

P	2	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7
	1.9	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6
	1.8	1.4	1.5	1.6	1.7	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.4	4.5
	1.7	1.3	1.4	1.5	1.6	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.3	4.4
	1.6	1.2	1.3	1.4	1.5	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.2	4.3
	1.5	1.1	1.2	1.3	1.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.1	4.2
	1.4	1	1.1	1.2	1.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	4	4.1	4.2	4	4.1
	1.3	0.9	1	1.1	1.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.9	4	4.1	3.9	4
	1.2	0.8	0.9	1	1.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.8	3.9	4	3.8	3.9
	1.1	0.7	0.8	0.9	1	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.7	3.8	3.9	3.7	3.8
	1	0.6	0.7	0.8	0.9	1.5	1.6	1.7	1.8	1.9	2	2.6	2.7	2.8	2.9	3	3.6	3.7	3.8	3.6	3.7
	0.9	0.5	0.6	0.7	0.8	1.4	1.5	1.6	1.7	1.8	1.9	2.5	2.6	2.7	2.8	2.9	3.5	3.6	3.7	3.5	3.6
	0.8	0.4	0.5	0.6	0.7	1.3	1.4	1.5	1.6	1.7	1.8	2.4	2.5	2.6	2.7	2.8	3.4	3.5	3.6	3.4	3.5
	0.7	0.3	0.4	0.5	0.6	1.2	1.3	1.4	1.5	1.6	1.7	2.3	2.4	2.5	2.6	2.7	3.3	3.4	3.5	3.3	3.4
	0.6	0.2	0.3	0.4	0.5	1.1	1.2	1.3	1.4	1.5	1.6	2.2	2.3	2.4	2.5	2.6	3.2	3.3	3.4	3.2	3.3
	0.5	0.1	0.2	0.3	0.4	1	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.1	3.2
	0.4	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	3	3.1
	0.3	-0	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	2.9	3
	0.2	-0	-0	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	2.8	2.9
	0.1	-0	-0	-0	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	2.7	2.8
N	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
	B																				F

Figure 7.1: 1 Leader Normal

P	2	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.4
	1.9	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3
	1.8	0.7	0.8	0.8	0.9	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.3	2.2	2.3
	1.7	0.7	0.7	0.8	0.8	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.3	2.2	2.2
	1.6	0.6	0.7	0.7	0.8	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2	2	2.1	2.1	2.2	2.2	2.1	2.2
	1.5	0.6	0.6	0.7	0.7	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	2.1	2.1	2.2	2.1	2.1
	1.4	0.5	0.6	0.6	0.7	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	2	2.1	2.1	2	2.1
	1.3	0.5	0.5	0.6	0.6	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	2	2	2.1	2	2
	1.2	0.4	0.5	0.5	0.6	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.9	2	2	1.9	2
	1.1	0.4	0.4	0.5	0.5	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.9	1.9	2	1.9	1.9
	1	0.3	0.4	0.4	0.5	0.8	0.8	0.9	0.9	1	1	1.3	1.4	1.4	1.5	1.5	1.8	1.9	1.9	1.8	1.9
	0.9	0.3	0.3	0.4	0.4	0.7	0.8	0.8	0.9	0.9	1	1.3	1.3	1.4	1.4	1.5	1.8	1.8	1.9	1.8	1.8
	0.8	0.2	0.3	0.3	0.4	0.7	0.7	0.8	0.8	0.9	0.9	1.2	1.3	1.3	1.4	1.4	1.7	1.8	1.8	1.7	1.8
	0.7	0.2	0.2	0.3	0.3	0.6	0.7	0.7	0.8	0.8	0.9	1.2	1.2	1.3	1.3	1.4	1.7	1.7	1.8	1.7	1.7
	0.6	0.1	0.2	0.2	0.3	0.6	0.6	0.7	0.7	0.8	0.8	1.1	1.2	1.2	1.3	1.3	1.6	1.7	1.7	1.6	1.7
	0.5	0.1	0.1	0.2	0.2	0.5	0.6	0.6	0.7	0.7	0.8	1.1	1.1	1.2	1.2	1.3	1.6	1.6	1.7	1.6	1.6
	0.4	0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	1.5	1.6
	0.3	-0	0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	1.5	1.5
	0.2	-0	-0	0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	1.4	1.5
	0.1	-0	-0	-0	0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	1.4	1.4
N	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2
	B																				F

Figure 7.2: 1 Leader Low

7.4.1 Proposed Research Questions: Dynamic cost/reward

1. Does the strength of group leadership change costs for group member action?

2. Does the strength of a group leadership change the perceived costs for group member action?

3. Does the dynamic cost of action change actual outcomes or only game scores?

7.5 Sub Group Formation

In mod-SYMLOG game 4 (21/01/2019) 6 participants played Austro-Hungary (A), England (E), France (F), Germany (G), Italy (I), and Russia (R). The node diagram for turn 5 (see Figure 7.4) shows a sub-group emerging within the game. This sub-group consists of Russia, Germany, and Austro-Hungary which begins to form between turns 4 (Figure 7.3) and 6 (Figure 7.5). In turn 4 Austro-Hungary has positive teamwork orientated interactions between Germany and Russia who are in opposition interactions between each other. In turn 5 positive teamwork interactions exist between Austro-Hungary, Germany, and Russia, while Austro-Hungary and Russia have oppositions interactions with England and Austro-Hungary and Germany have oppositions interactions with France. This shows a shift in a group where Austro-Hungary, Germany, and Russia align as a single group which is maintained into turn

6.

Interestingly, while the core group of Austro-Hungary, Germany, and Russia move into a cooperative relationship members maintain positive relations with external participants even if those participants are in conflict with other team members. For example Germany maintains positive interactions with England while England is in opposition with Russia. The cooperation between England and Germany appears to be beneficial to the group as England moves from positive interactions with France in turns 4 and 5 to oppositional interactions in turn 6 and from oppositional interactions with Russia in turns 4 and 5 to teamwork in turn 6.

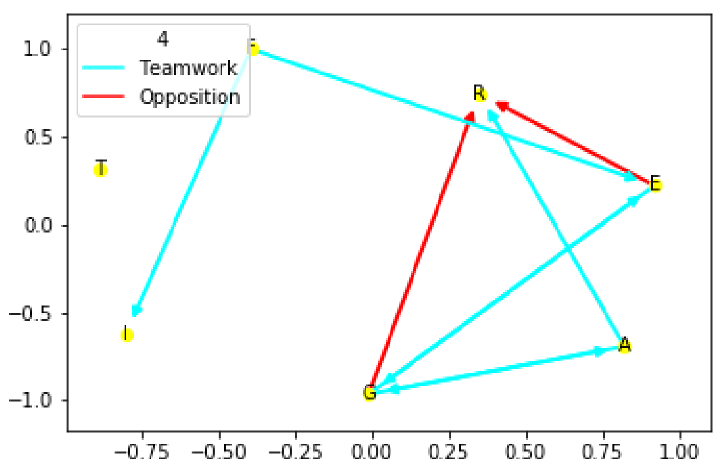


Figure 7.3: Diplomacy Game 4 Turn 4 Node Diagram

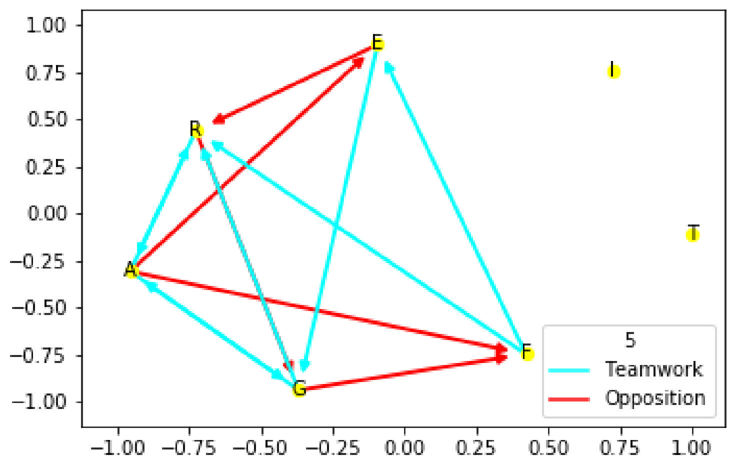


Figure 7.4: Diplomacy Game 4 Turn 5 Node Diagram

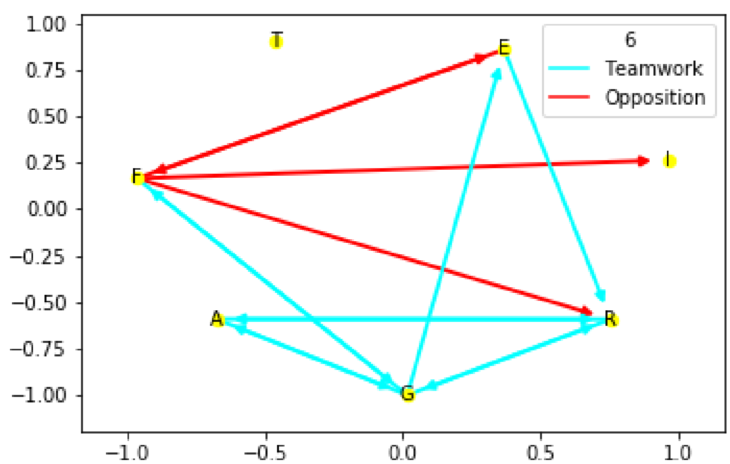


Figure 7.5: Diplomacy Game 4 Turn 6 Node Diagram

Country	Turn	A	E	F	G	I	R
A	4				UPF	DP	PF
E	4				PF,P		D
F	4		PF		DF	DPF	UB
G	4	PF	P, PF, PF				UN,UNB,F
I	4	DN					
R	4	PF					
A	5		B	D	UPF		UP
E	5				UPF		B
F	5	DF	DPF		UB	DF	PF
G	5	P,PF		NB			P,PF
I	5						
R	5	P,PF			PF, DNB		
A	6		DF		UF	DP	UF
E	6			UNB	UB		UP
F	6		DB		DPF	DNB	UNB
G	6	PF	DF,DPF	DF,DP,UP			PF
I	6						
R	6	P,PF	DF		PF		

Table 7.4: Diplomacy Game 4 Mod-SYMLOG Turns 2 - 5

7.5.1 Proposed Research Questions: Sub Group

1. Can sub group formation be detected automatically?

2. Can sub group formation be predicted?

7.6 Group Score

7.6.1 Mod-Snowdrift Game Scores

Data from 4 games of Diplomacy used to test the mod-SYMLOG system have been reused to produce example scores from using mod-Snowdrift payouts. Tables 7.5 and 7.6 compare the scores generated from the classic Snowdrift game, the modified version from the payout matrices above, the amount of Cooperative (C) interactions, the amount of Hard Cooperative (HC) interactions, Defection (D) interactions, Hard Defection (HD) interactions, and the total amount of interactions. The difference between C and HC are Cooperative Light (LC) plays and Defect Light (LD) is the difference between D and HD. In each game, the amount of C/HC interactions appears to be a better indicator of who won the game rather than the individual score. Groups are mobile, players can join (C/HC/LC), leave (D/LD/HD) and rejoin (C/HC/LC) a group during any series of long term social interactions.

This group score can be investigated by using data from mod-SYMLOG game 4 held on 21/01/2019. Using the identified subgroup in Section 7.5, the mod-Snowdrift group scores can be calculated by summing the individual scores of the 3 members Austro-Hungary (A), Germany (G), and Russia (R). with a total of 1,575 (A: 675 + G: 300 + R: 600 see Table 7.5) for turn 5 and 2,150 (A: 675 + G: 850 + R: 625 see Table 7.6) in turn 6.

	A	E	F	G	I	R	T
Classic	700	500	400	200	0	700	0
Modified	675	500	400	300	0	600	0
Cooperative	2	1	4	2	0	2	0
Hard Cooperative	1	1	2	2	0	1	0
Defection	1	1	1	1	0	1	0
Hard Defection	0	1	1	1	0	0	0
Interactions	3	2	5	3	0	3	0

Table 7.5: Diplomacy Game 4 Snowdrift Turn 5

	A	E	F	G	I	R	T
Classic	600	800	100	900	0	600	0
Modified	675	550	150	850	0	625	0
Cooperative	3	1	1	3	0	3	0
Hard Cooperative	0	0	1	3	0	2	0
Defection	0	2	3	1	0	0	0
Hard Defection	0	2	3	0	0	0	0
Interactions	3	3	4	4	0	3	0

Table 7.6: Diplomacy Game 4 Snowdrift Turn 2

A more complex example with 2 groups can be found in game 3 which also took place on 21/01/2019. In turn 5 with 1 group consisting of Austro-Hungary, Italy (I) and Russia and a second of England (E), France (F), Germany with Turkey (T) cooperating with both groups (see Figure 7.6). The mod-Snowdrift group score for group 1 is 2275 (A: 350 + I: 925 + R: 1000) and for group 2 is 625 (E: 200 + F: 225 + G: 200) with T having a score of 1075 (see Table 7.7). At the end of the game group 1 (Austro-Hungary, Italy, and Russia) shared the largest number of territories as well as the largest group score, with Russia, Austro-Hungary, and Turkey being the top 3 countries by size. In-game the high levels of cooperation of group 1 and the diplomatic skills of Turkey allowed more coordinated teamwork between group members.

However; as outlined in Section 2.1 groups can outperform what individuals can achieve by themselves, therefore these aggregated scores potentially do not capture the full performance of the group. In Chapter 6 experiment 2 an example bonus of 10% was added to represent this increased performance of the group work. As noted with social psychology (Section 2.2.1) groups are not linear containing structured hierarchies and members can be distributed between a core group and various periphery levels further away from the core and closer to other groups.

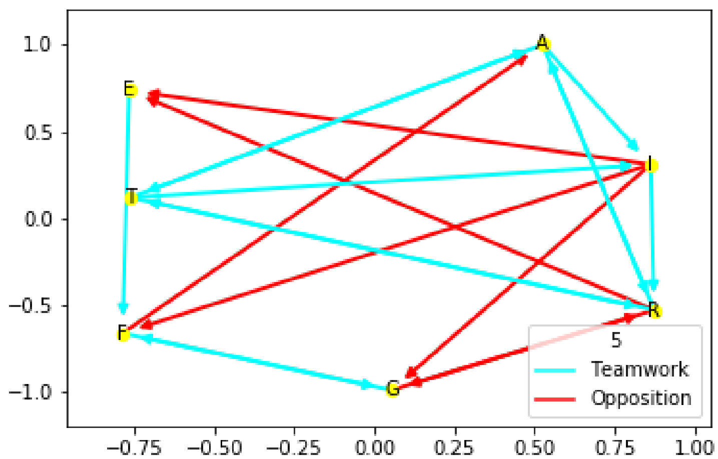


Figure 7.6: Diplomacy Game 4 Turn 6 Node Diagram

	A	E	F	G	I	R	T
Classic	400	200	200	200	1400	1000	1000
Modified	350	200	225	200	925	1000	1075
Cooperative	2	2	2	2	1	2	5
Hard Cooperative	2	1	0	1	0	2	2
Defection	0	0	2	2	4	2	0
Hard Defection	0	0	1	2	3	2	0
Interactions	2	2	4	4	5	4	5

Table 7.7: Diplomacy Game 3 Snowdrift Turn 5

7.6.2 Proposed Research Questions: Group Score

1. Does group score provide a better predictor of winners than individual scores?

2. Can group scores be tiers between a core group and periphery members?

3. What method is best to calculate group scores across multiple interactions?

4. Do groups require a bonus score to more accurately represent the ability of groups to outperform the collection of individual members?

5. What amount of bonus score is required to accurately reflect group work?

6. Is this bonus score dependant on levels of group cooperation?

7. Does there need to be multiple bonus scores of group members depending on their position within a group?

Chapter 8

Conclusion

This thesis has reviewed the advantages and disadvantages of group work in the classroom. One of the main issues with group work cited in the literature is that while groups with high levels of cooperation and cohesion lead to better learning and social-emotional outcomes however those with low co-operation can lessen or negate learning and also potentially lead to learners self excluding from future education and socialisation. After investigating different schools of psychology, the group framework of SYMLOG was selected as a good tool to model groups and the individual relationships, in the forms of interactions, between group members. SYMLOG was then modified by rating interactions between group members via a 3 axes system rather than adjectives. Modified SYMLOG was then used as the bases of forming The Group Model. The Group Model allowed for the creation of group based Intelligent Tutoring System (ITS) encompassing the whole classroom from individual learners to groups and incorporating the teacher into a framework to support all aspects of teaching and this has been named the Intelligent Classroom Tutoring System (ICTS). To achieve this the ICTS incorporates the ITS to support individual students and adds additional modules for group pedagogies (Group Pedagogy Module), user interfaces for groups (Group User Interface), and an AI system (Third Teacher). Each of these roles are defined in more detail in Chapter 3.

In Section 1.3 11 research questions were asked with the aim to investigate various aspects of the ICTS. The questions are re-listed here:

1. Can either Europa Universalis 4 or Diplomacy be used in order to test mod-SYMLOG?
2. Can mod-SYMLOG capture the interactions between groups?
3. Can mod-SYMLOG capture the formation of sub-groups?
4. Can mod-SYMLOG be used to track groups long term?
5. Are mod-SYMLOG diagrams (SFD, 3D-SFD, and node diagrams) useful to group supervisors to monitor groups?
6. Can mod-SYMLOG diagrams be used to predict grades?
7. Can mod-SYMLOG diagrams be used to predict group breakdown?
8. Which Prisoner's Dilemma strategy achieves the highest score in a game of modified Snowdrift?

9. After how many turns do players stop engaging with Snowdrift strategies?
10. Does using the mod-SYMLOG node diagram allow more accurate ratings of group cooperation compared with only analysing final game scores?
11. Can players accurately assess total contribution of groups from mod-SYMLOG diagrams alone?

Questions 1, 2, and 3 were answered in Chapter 4. In this Chapter SYMLOG was tested with the computer game Europa Universalis 4 (EU4) and the board game Diplomacy to find a reliable and valid framework for testing of mod-SYMLOG. In these experiments it was found that while EU4 provided high levels of reliability there were some questions of validity when it came to applying the results beyond a virtual system. Diplomacy when tested showed itself to be both reliable and valid as, while it was abstracted through board game rules, most of the interactions were a mixture of emotional and rational responses to situations in a manner that the researchers considered similar to real world groups interactions. Mod-SYMLOG was then tested using Diplomacy and it was found that it could both track interactions between group members and show the formation and politics of sub-groups. Thereby answering our research questions on mod-SYMLOG's abilities to monitor groups.

In Chapter 5 questions 4, 5, 6, and 7 were attempted to be answered. Here an experiment was run to test the effectiveness of mod-SYMLOG in a longitudinal study both focusing on the learners, their group cohesion and performance, and assessing the utility to group supervisors. Unfortunately with only 70/453 (15%) of learners from the 1st and 2nd year undergraduate cohorts signing the consent form and with a very small number of those groups that have more than 1 person providing data, this meant that no meaningful data could be collected. However the running of the experiment itself demonstrated the viability of running such an experiment with a better incentive for students to partake.

Finally questions 7, 8, 9, 10 and 11 were used to design experiments in Chapter 6. The first experiment showed that, compared to a Prisoner's Dilemma framework, mod-Snowdrift benefited cooperative strategies more than defecting strategies. The next step was to see when human players stopped engaging with various strategies in a game of mod-Snowdrift. When comparing the modal value of plays all strategies with the exception of the Defector and Cooperator Spite saw the majority of players playing a full 50 turns against each strategy. This is reinforced when comparing the mean value, as even the light defecting strategies had significantly more engagement than hard defecting strategies. This suggests that participants were more willing to engage with strategies that were giving a small amount to the group than participants that contributed nothing. When it comes to group work in a classroom setting, the results imply that a single defection would not necessarily lead to a break down in communication but with 3 or 4 defections from group work, would lead to disunity within the group. This information could be used to generate a warning to the First Teacher to intervene and make decisions on how to resolve issues. The final experiment in Chapter 6 examined the usefulness of node diagrams in estimating group work. Participants were asked to estimate group cohesion and performance of group work. Participants were provided with single turn examples of a mod-Snowdrift game showing the results of a single turn of interaction and asked to rate how cooperative the group was being and what the total financial gain would be from these games. While there may have been some training bias in the experiment, groups where the interactions were presented with either a node diagram or node diagram and totals of group work were significantly more accurate in estimating how cooperative groups were compared to when being provided with the totals only. This experiment showed the effectiveness of the node diagrams as an aid to teachers in over seeing group work.

In Chapter 4 this research showed node diagrams with binary ratings of either allied/rival for EU4 games or teamwork/opposition for games of Diplomacy. A more nuanced rating can be achieved with the quaternary division of interactions introduced via mod-Snowdrift, as seen in Chapter 6. It is possible to encode mod-SYMLOG ratings directly as levels of cooperation to that can be expressed as a node diagram. As with Bales original division of group members within areas of a graph (see Figure 2.1) one can divide areas of either a SFD or 3D-SFD plotted using mod-SYMLOG into regions of cooperation. This would allow node diagrams to be created simultaneously with the mod-SYMLOG rating of group interactions.

Experiment 3 in Chapter 6 was designed to supplement the finding from the research question 2 in Chapter 5, where this question aimed to investigate how useful node diagrams were to group supervisors. While the longitudinal study in Chapter 5 was unable to produce the required data, the experimental results in Chapter 6 supports replicating the Chapter 5 study to access the usefulness of node diagrams in real world groups. This provides evidence that can be used to partially answer question 5.

One limitation of the research done is that all populations in each of the studies were adults and thus the level of their psychosocial development was not a major consideration within the experimental framework and thus restricts the results to an adult population. This should not be an issue with the First Teacher aspects of the ICTS, but will have an impact on the Third Teacher parameters when monitoring of groups and the Group Model. Types feedback given to students via the Group User Interface Module will also have to take into account the developmental level of the learner population.

In Chapter 1 this thesis highlighted the problem of an increasing student to teacher ratio in Secondary Education in the UK. The work in this thesis aimed at designing a framework to support human teachers within educational settings, using ICTS. By treating teachers as professionals and providing them with easy to interpret information, the ICTS supports the teacher by allowing them to make informed decisions about how to organise their classrooms. The ICTS, through The Group Model, provides information to the teacher about the status of groups during group work sessions, and provides a predictive mechanism to alert the teacher to potential issues that may occur between group members.

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Appendices

Appendix A

AI vs AI SYMLOG Code Samples

A.1 symlog_type.py

```
def symlog_type(attitude):
    if attitude == 'neutral' :
        symlog = 'DN'
    elif attitude == 'hostile' :
        symlog = 'U'
    elif attitude == 'rivalry' :
        symlog = 'UNB'
    elif attitude == 'outraged' :
        symlog = 'NB'
    elif attitude == 'defensive' :
        symlog = 'PB'
    elif attitude == 'friendly' :
        symlog = 'UB'
```

```
    elif attitude == 'protective' :
        symlog = 'UPB'
    elif attitude == 'loyal' :
        symlog = 'DPF'
    elif attitude == 'disloyal' :
        symlog = 'DB'
    elif attitude == 'rebellious' :
        symlog = 'NB'
    elif attitude == 'overlord' :
        symlog = 'F'
    elif attitude == 'domineering' :
        symlog = 'UNF'
    elif attitude == 'threatened' :
        symlog = 'N'
    else:
        symlog = ''
    return(symlog)
```

A.2 EU4_Save_Country_Profiler22.py

```python
import glob
import re
from cor_caller import cor_caller
from symlog_type import symlog_type
from data_cleaner import data_cleaner
from Active_Genorator import Active_Genorator
import matplotlib.pyplot as plt
import matplotlib.pyplot as plt2
import numpy as np
from network_node_gen import network_node_gen
from rival_cleaner import rival_cleaner
from name_cleaner import name_cleaner
from changed_name_cleaner import changed_name_cleaner
import statistics
import networkx as nx
import matplotlib.lines as mlines

years = []
count = 0
```

```python
data = []
i = 0
C_Name = ''
AC_Name = ''
Full_Name = ''
prev_dict = {'Short_Name' : 'blank'}
dict_Country = {'Short_Name' : '', 'Rivals' : '',
'current_opinion' : '', 'Ally' : ''}
Ally_List = ''
Subject_List = ''
War_List = ''
War_Ally_List = ''
Rival_List = ''
list_dict = []
current_op = 0
att_country = ''
relation_opinion = ''
Active_Countries = []
AC_Size = 0
```

```python
start_recording = False
last_country = False
c=0
all_data = []
list_of_opinions = []
flag_active = False
xlist = []
ylist = []
zlist = []
clist = []
colourlist = []
C_in_list = []
list_of_lists = []
graph_creator = {'Short_Name' : 'blank'}
graph_list = []
colourlist = [ 'salmon', 'slateblue', 'lawngreen', 'tan', 'darkslategray',
'turquoise', 'maroon', 'sandybrown', 'cyan', 'g', 'darkkhaki', 'lightcyan',
'dimgrey', 'darkcyan', 'gray', 'lightcyan', 'mediumblue', 'gainsboro',
'darksalmon', 'lightslategrey', 'moccasin', 'darkorange', 'lightskyblue',
```

```
'fuchsia',]


def dict_creator(dict_Country):
    dict_Country['Rivals']=Rival_List
    dict_Country['current_opinion'] = relation_opinion
    if "Number_Of_Cities" not in dict_Country
    or dict_Country['Number_Of_Cities']
    == '' or dict_Country['Number_Of_Cities'] == '0':
        dict_Country.clear()
        dict_Country = {'Short_Name' : 'blank', 'Ally' : ''}
    if prev_dict['Short_Name'] != dict_Country['Short_Name']:
        #print(dict_Country)
        list_dict.append(dict_Country.copy())
        list_of_opinions.append(relation_opinion)
        dict_Country.clear()
        dict_Country = {'Short_Name' : 'blank', 'Ally' : ''}
    prev_dict['Short_Name'] = dict_Country['Short_Name']

```

```
for filename in glob.glob('*eu4'):
    count = count + 1
tot_count = count

for filename in glob.glob('*eu4'):
    file_name = filename
    print(count, "/", tot_count)
    i = 0

    data, date = data_cleaner(file_name)
    date = date.replace(".","")

    #Active_Countries = ['GBR','HAB', 'POR', 'ENG']
    #Active_Countries_Full = ['England','Austria','Portugal']
    Active_Countries, Active_Countries_Full = Active_Genorator(data)

    i = 0
    while i < len(data):
        try:
```

```
j =i+1
k = j+1
m = i-1
if "government_rank" in data[j] and
re.search(r"[0-9A-Z]{3}=\{", data[i]):
    flag_active = False

if "has_set_government_name" in data[j]:
    dict_creator(dict_Country)
    Ally_List = ''
    Subject_List = ''
    War_List = ''
    War_Ally_List = ''
    Rival_List = ''
    C_Size = 0
    relation_opinion = ''
    if re.search(r"[A-Z]{3}=\{", data[i]):
        C_Name = data[i]
    elif re.search(r"[A-Z]{3}=\{", data[m]):
```

```
            C_Name = data[m]
        else:
            C_Name = ''
        C_Name = C_Name.strip()
        C_Name = C_Name[:-2]
        dict_Country = {'Short_Name': C_Name, 'Year': date,
        'Ally' : ''}
        if C_Name in Active_Countries:
            flag_active = True
        else:
            flag_active = False

    if "overlord=" in data[i]
    and flag_active == True:
        OverLord = data[i]
        OverLord = OverLord.strip()
        OverLord = OverLord[10:-1]
        dict_Country['OverLord'] = OverLord

```

```
if "rival=\{" in data[i] and "date=" in data[k]
and flag_active == True:
    Rival_List = rival_cleaner(data[i+1], Rival_List)

if "allies={" in data[i] and "extended_allies" not in data[i]
and flag_active == True:
    a = i+1
    while "}" not in data[a]:
        Ally = data[a]
        Ally = Ally.strip()
        Ally = Ally.replace('"','')
        a = a + 1
        if Ally_List == '':
            Ally_List = Ally
        else:
            Ally_List = Ally_List + ',' + Ally
    dict_Country['Ally'] = Ally_List

if "subjects={" in data[i] and flag_active == True:
```

```
            s = i+1
            while "}" not in data[s]:
                Subject = data[s]
                Subject = Subject.strip()
                Subject = Subject.replace('"','')
                if Subject_List == '':
                    Subject_List = Subject
                else:
                    Subject_List = Subject_List + ',' + Subject
                s = s + 1
            dict_Country['Subjects']=Subject_List


        if "current_at_war_with={" in data[i] and flag_active == True:
            w = i+1
            while "}" not in data[w]:
                War = data[w]
                War = War.strip()
                War = War.replace('"','')
```

```
            if War_List == '':
                War_List = War
            else:
                War_List = War_List + ',' + War
            w = w + 1
        dict_Country['War']=War_List

    if "current_war_allies={" in data[i] and flag_active == True:
        wa = i+1
        while "}" not in data[wa]:
            War_Ally = data[wa]
            War_Ally = War_Ally.strip()
            War_Ally = War_Ally.replace('"','')
            wa = wa + 1
            if War_Ally_List == '':
                War_Ally_List = War_Ally
            else:
                War_Ally_List = War_Ally_List + ',' + War_Ally
        dict_Country['War_Ally']=War_Ally_List
```

```

if "name=" in data[i] and "adjective=" in data[i+1]
and flag_active == True:
    Full_Name = name_cleaner(data[i])
    dict_Country['Full_Name']=Full_Name

if "changed_country_name_from" in data[i] and flag_active == True:
    Full_Name = changed_name_cleaner(data[i])
    dict_Country['Full_Name']=Full_Name

if "num_of_cities" in data[i] and flag_active == True:
    C_Size = data[i]
    C_Size = C_Size.strip()
    p = C_Size.find("=")
    C_Size = C_Size[p+1:]
    dict_Country['Number_Of_Cities']=C_Size

if "active_relations={" in data[i] and flag_active == True
and dict_Country['Short_Name'] in Active_Countries:
```

```
i=i+1
co = False
while "decision_seed" not in data[i]:
    if re.search(r"[A-Z]{3}={", data[i]):
        current_op = ''
        asd = data[i]
        att_country = ''
        try:
            att_country = dict_Country['Full_Name']
        except:
            att_country = 'N/A'
        att_country2 = asd[:-3]
        att_country2 = att_country2.strip()

    if "attitude" in data[i] and att_country2 in
    Active_Countries:
        current_op = data[i]
        current_op = current_op.strip()
        p = current_op.find("_")
```

```
current_op = current_op[p+1:-1]
current_op = current_op


if current_op != "attitude=ye":
    if att_country in Active_Countries_Full:
        symlog_op = current_op
        normalised = symlog_type(symlog_op)
        normalised = normalised.strip()
        if len(normalised) == 3:
            nor_cor_caller = cor_caller(normalised)
        else:
            cor_list = []
            if 'U' in normalised:
                cor_list.append("U")
            if 'D' in normalised:
                cor_list.append("D")
            if 'P' in normalised:
                cor_list.append("P")
```

```
if 'N' in normalised:
    cor_list.append("N")
if 'B' in normalised:
    cor_list.append("B")
if 'F' in normalised:
    cor_list.append("F")

if ('U') not in normalised
and ('D') not in normalised:
    cor_list.insert(0,1)
if ('N') not in normalised
and ('P') not in normalised:
    cor_list.insert(1,1)
if ('B') not in normalised
and ('F') not in normalised:
    cor_list.insert(2,1)

nor_cor_caller = cor_caller(cor_list)
if att_country2 in
```

```
                dict_Country['Ally']:
                  nor_cor_caller[0]=nor_cor_caller[0]+0.5
                  nor_cor_caller[1]=nor_cor_caller[1]+0.5
                  nor_cor_caller[2]=nor_cor_caller[2]+0.5
              co = True
              cor_list = []
        if co == True:
          if relation_opinion == '':
            relation_opinion = att_country + "_"
            + str(nor_cor_caller)
          else:
            relation_opinion = relation_opinion
            + "," + att_country + "_" + str(nor_cor_caller)
          co = False

        i=i+1
except IndexError:
  pass
i= i + 1
```

```python
data = []
count = count - 1

i = 0
list_of_opinions = str(list_of_opinions).split("],")
for opinion in list_of_opinions:
    if not re.search(r"]", opinion):
        opinion = opinion + "]"
        list_of_lists.append(opinion)
    if re.search(r"', '", opinion):
        opinion = opinion.split("',")
        for sub_opinion in opinion:
            sub_opinion = sub_opinion.replace("'","")
            sub_opinion = sub_opinion.strip()
            if not re.search(r"]", sub_opinion):
                sub_opinion = sub_opinion + "]"
                list_of_lists.append(sub_opinion)
            else:
                list_of_lists.append(sub_opinion)
```

```python

for opinion in list_of_lists:
    if len(opinion) < 10:
        continue
    st = opinion.split("_")
    if not any(d['Full_Name'] == st[0] for d in graph_list):
        graph_list.append({'Full_Name' : st[0]})
for opinion in list_of_lists:
    st = opinion.split("_")
    for c in graph_list:
        name = c['Full_Name']
        name = name.replace("['", "")
        c['Full_Name'] = name
        #print(name)
        if c['Full_Name'] == st[0]:
            if "Opinion" in c:
                c['Opinion'] =  c['Opinion'] + "," + st[1] + ";"
            else:
                c['Opinion'] = ";," + st[1] + ";"
```

```

UD = []
NP = []
FB = []
length_count = 0
bob = ''
for d in graph_list:
    length_count = 0
    UD = []
    NP = []
    FB = []
    now_that = []
    iamdoingthisreallywrong = d['Opinion'].split(";")
    for i in range(len(iamdoingthisreallywrong)):
        if iamdoingthisreallywrong[i] == '':
            continue
        fred = iamdoingthisreallywrong[i].split()
        for now_this in fred:
            now_this = now_this.replace("[","").replace("]","")
```

```
                    .replace(",","")
                    now_that.append(now_this)
                UD.append(float(now_that[0]))
                NP.append(float(now_that[1]))
                FB.append(float(now_that[2]))
                now_that = []

            if d['Full_Name'] not in clist:
                xlist.append(statistics.mean(UD))
                ylist.append(statistics.mean(NP))
                zlist.append(statistics.mean(FB))
                clist.append(d['Full_Name'])
                length_count = 0

        graph_list.clear()
        list_of_lists.clear()
        list_of_opinions.clear()
        x, y, z = (xlist, ylist,zlist)
        #print(xlist, ylist,zlist)
```

```
fig = plt.figure(figsize=(10,10))
ax = fig.add_subplot(111, projection='3d')
plt.xlim(0,2)
plt.ylim(0,2)
ax.set_zlim(0,2)
fred = str(date + ' Top ' + str(len(clist)) + ' Countries')
plt.title(fred)
for i in range(len(xlist)): #plot each point + it's index as text above
    ax.scatter(xlist[i],ylist[i],zlist[i], alpha=0.8,
    color=colourlist[i], label=clist[i])
    ax.text(xlist[i],ylist[i],zlist[i],  '%s' % (str(clist[i])),
    size=10, zorder=1, color='k')
    print(xlist[i],ylist[i],zlist[i],clist[i])

ax.set_xlabel('Submissive < -- > Dominating')
ax.set_ylabel('Negative Behaviour < -- > Positive Behaviour')
ax.set_zlabel('Rejecting Authority < -- > Accepting Authority')
ax.legend(bbox_to_anchor=(1.05, 1), loc=2, borderaxespad=0.)
```

```python
filename = date + '_3D.png'

def drawSphere(xCenter, yCenter, zCenter, r):
#draw sphere
    u, v = np.mgrid[0:2*np.pi:20j, 0:np.pi:10j]
    x=np.cos(u)*np.sin(v)
    y=np.sin(u)*np.sin(v)
    z=np.cos(v)
    # shift and scale sphere
    x = r*x + xCenter
    y = r*y + yCenter
    z = r*z + zCenter
    return (x,y,z)


x = 1.5
y = 1.5
z = 1.5
r = 0.75
```

```

#draw a sphere for each data point
(xs,ys,zs) = drawSphere(x,y,z,r)
ax.plot_wireframe(xs, ys, zs, color="green", alpha=0.3)

x = 0.5
y = 0.5
z = 0.5
r = 0.75

(xs,ys,zs) = drawSphere(x,y,z,r)
ax.plot_wireframe(xs, ys, zs, color="red", alpha=0.3)
plt.savefig(filename)

G = nx.Graph()
edges = []
edges2 = []
for line in list_dict:
    for key in line:
```

```
        #print(line)
        if key == 'Short_Name':
            #print(line['Short_Name'])
            #England, France, Austria, Ottomans, Moscovy, Russia,
            Brandanburg, Prussia, Great Britian
            if line[key] in ['ENG','FRA','HAB','TUR','MOS','RUS','BRA',
            'PRU','GBR' ]:
                #print(line)
                G.add_node(line[key])
                #print("{}: {}".format(key, a[key]))
                l = line['Rivals'].split(",")
                for thing in l:
                    one_argument = line[key], thing
                    edges.append(one_argument)
                    #print(edges)
                if 'Ally' in line:
                    q = line['Ally'].split(",")
                    for thing2 in q:
                        two_arguement = line[key], thing2
```

```
                        edges2.append(two_arguement)

G.add_edges_from(edges)
G.add_edges_from(edges2)
print(G.node)
print(edges)
print(edges2)

pos = nx.spring_layout(G, k=0.3) # positions for all nodes

# nodes
nx.draw_networkx_nodes(G,pos,node_size=40, node_color='yellow')

# labels
nx.draw_networkx_labels(G,pos,font_size=10,font_family='sans-serif')

# edges
#colours = [G[u][v]['color'] for u,v in edges]
nx.draw_networkx_edges(G,pos,edgelist=edges, width=2, edge_color='r')
```

```
nx.draw_networkx_edges(G,pos,edgelist=edges2, width=2, edge_color='cyan')

# weights
labels = nx.get_edge_attributes(G,'weight')
nx.draw_networkx_edge_labels(G,pos,edge_labels=labels)

#legand
blue_line = mlines.Line2D([], [], color='cyan', label='Allied')
reds_line = mlines.Line2D([], [], color='red', label='Rivaled')

plt.legend(title=date, handles=[blue_line, reds_line])

graph_save = date + '_EU4_Network_Graph.png'
plt.savefig(graph_save, format='PNG')
plt.show(block=False)
count = count - 1
```

Appendix B

AI vs AI SYMLOG Additional Output

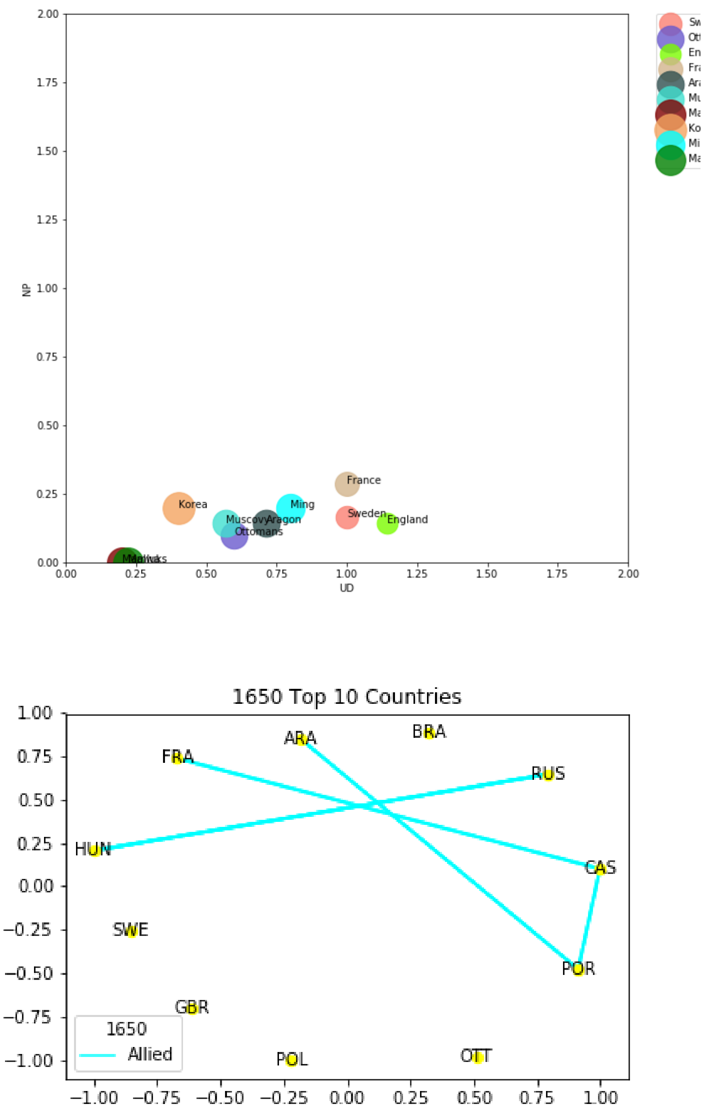
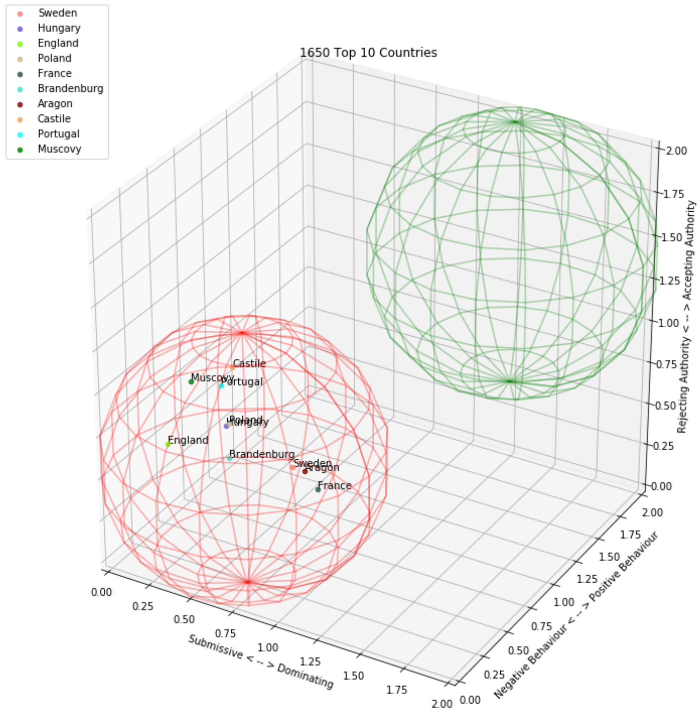


Figure B.1: EU4 1545 2D and 1650 Node Diagram



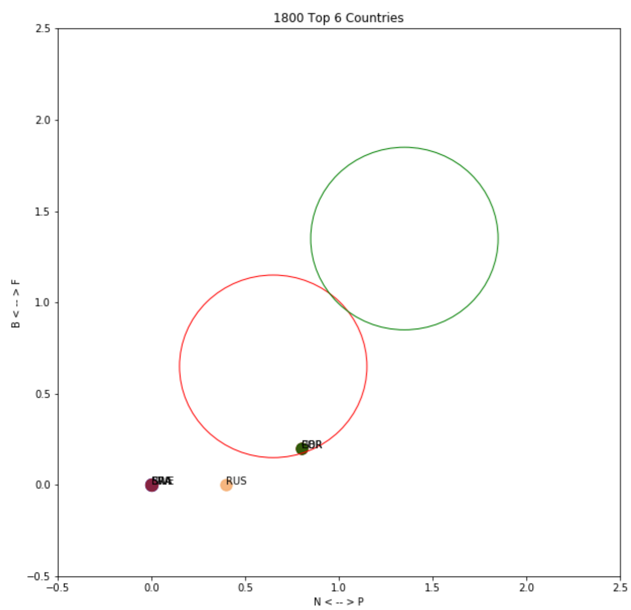


Figure B.2: EU4 1650 3D and 1800 Node Diagram

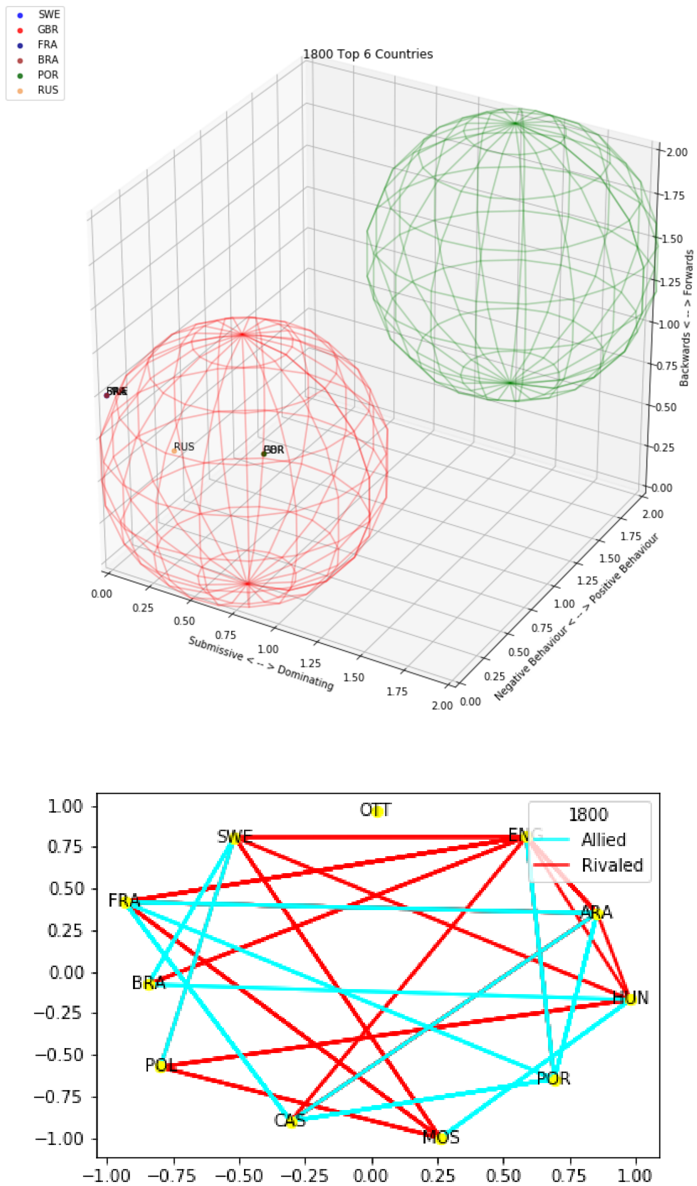


Figure B.3: EU4 1800 3D And Node Diagram

Appendix C

Human Vs Human Diplomacy Experiments Raw Data - SYMLOG And Mod-SYMLOG

C.1 SYMLOG Game 1 23/10/18

Country	Turn	AH	EN	FR	GE	RU	TU
AH	1		PF	DF		PF, DF	N
EN	1	UF		U, DN, NB, N		DB	DPB
FR	1						
RU	1	U	UNF, UN	NF, N, NB			UP, UNB
TU	1	DB	DPB			UN	
AH	2		UPF	UPF		NB	DB, NB

EN	2	UPF		U		DNF	DPB
FR	2						
RU	2		DPB				UPF
TU	2	F		UPF		UPF	
AH	3		F, PF	F, PF		DB	UN, DN
EN	3	DNF		N		U	PB
FR	3						
RU	3			PB, B,DF			UF, UNF
TU	3	DN	F			DPF	
AH	4		F, PF	F, PF		DB	UN, DN
EN	4	UPF		F, PF			
FR	4						
RU	4		UNB				UF
TU	4	UNF, UNB, UN				UB, P	
AH	5		PF, P	PF, P		PF	DB
EN	5					U	
FR	5						
RU	5						
TU	5	UN	P, B				
AH	6		P, PF	P, PF			
EN	6			U, DN			
FR	6						
RU	6						

TU	6	UNB	PF			UF	
AH	7		P, PF	NB		PB, UPB	DN, DNB
EN	7						
FR	7						
RU	7						
TU	7		P, B			UN	
AH	8		F, PF			PB, UPB	
EN	8					UPF	PB
FR	8						
RU	8						
TU	8	UN	N			U, UB	

Table C.1: SYMLOG Diplomacy Game 1

C.2 SYMLOG Game 2 23/10/18

Country	Turn	AH	EN	FR	GE	RU	TU
AH	1		UPF	UPF		PF	DB, NB
EN	1	UPF		U		DNF	DPB
RU	1		DPB				UPF
TU	1	F		UPF		UPF	
AH	2		PF	DF		PF, DF	N

EN	2	UF		U, DN, NB, N		DB	DPB
RU	2	U	UNF, UN	NF, N, NB			UP, UNB
TU	2	DB	DPB			UN	
AH	3		F, PF	F, PF		DB	UN, DN
EN	3	UPF		F, PF			
RU	3		UNB				UF
TU	3	UNF, UNB, UN				UB, P	
AH	4		F, PF			DB	UN, DN
EN	4	DNF		N		U	PB
RU	4			PB, B,DF			UF, UNF
TU	4	DN	F			DPF	
AH	5		P, PF				
EN	5			U, DN			
RU	5						
TU	5	UNB	PF			UF	
AH	6		PF, P			PF	DB
EN	6					U	
RU	6						
TU	6	UN	P, B				
AH	7		F, PF			PB, UPB	
EN	7					UPF	PB
RU	7						
TU	7	UN	N			U, UB	

AH	8		P, PF	NB		PB, UPB	DN, DNB
EN	8						
RU	8						
TU	8		P, B			UN	

Table C.2: SYMLOG Diplomacy Game 2

C.3 Mod-SYMLOG Game 1 14/01/19

Country	Turn	AH	EN	FR	GE	RU	TU
AH	1				PF		DPF
AH	2						
AH	3					F	PF, PF
AH	4				P	FP	PF
AH	5			UP	UNF	DB	
AH	6						PF
AH	7			D		P	
AH	8						
Fr	1				PF, F	F	
Fr	2						
Fr	3				FP, F, P	FP, DPF	
Fr	4				PF, F	PF	

Fr	5	P, PF, DPF			PF	DF, DPF	UB
Fr	6						
Fr	7	DPF, D			PF, DPF	B	PF
Fr	8				DPF	NB	P, PF
Ge	1	P		PF		D	PF
Ge	2						
Ge	3			PF			UNB
Ge	4			PF			U
Ge	5	UP				DB	B
Ge	6						PB
Ge	7			UB			UB
Ge	8			UPB			B
IT	1	UP		UP			UP
IT	2						
IT	3	UP		UNB			UP
IT	4	UP		UN			UP
IT	5	UNB		UN, UNF			
IT	6						
IT	7	UNF					
IT	8	UP		UB			UP
Ru	1	DF					
Ru	2						
Ru	3	DF		N	NF	DP	

Ru	4	FP		N	UB	PF	
Ru	5	UPB		NB	DN	D	
Ru	6	P		NB	N	D	
Ru	7	UB		PB	D	DP	
Ru	8	DP		PF	U	U	

Table C.3: Mod-SYMLOG Diplomacy Game 1

C.4 Mod-SYMLOG Game 1 14/01/19

Country	Turn	AH	EN	FR	GE	RU	TU
AH	1		F		PF		PF, DP
En	1				PF		PF
Fr	1						
Ge	1	PF	UPF				F
IT	1						
Ru	1	PF, UPF	P,PF		P,PF		
Tu	1						
AH	2				D		
En	2				PD		PF
Fr	2						
Ge	2	UP					N

IT	2						
Ru	2	PF	P,PF		P,PF		
Tu	2						
AH	3						P
En	3				PF		P
Fr	3						
Ge	3						N
IT	3						
Ru	3	PF	PF		PF		
Tu	3						
AH	4						P
En	4	U			PF		PB
Fr	4						
Ge	4						
IT	4						
Ru	4	PF	PF		PF		
Tu	4						
AH	5				UNB		
En	5	D			UNB		PF
Fr	5						
Ge	5	UN	UN				UN
IT	5						
Ru	5	PF	PF		NB		

Tu	5						
AH	6						PF
En	6	P			N		B
Fr	6						
Ge	6	U	U				UB
IT	6						
Ru	6	PF	PF		D, DB		
Tu	6						
AH	7				D		DP
En	7	P			D		PF
Fr	7						
Ge	7	U	U				UN
IT	7						
Ru	7	PF	PF		DP,DB		
Tu	7						
AH	8				D		PF
En	8	P			DP		PB
Fr	8						
Ge	8	U	UN				UN
IT	8						
Ru	8	PF	PF		DP,DB		
Tu	8						

Table C.4: Mod-SYMLOG Diplomacy Game 2

C.5 Mod-SYMLOG Game 4 21/01/19

Country	Turn	AH	EN	FR	GE	RU	TU
AH	1				PF		DPF
EN	1						
FR	1				PF, F	F	
GE	1	P		PF		D	PF
IT	1	UP		UP			UP
RU	1	DF					
TU	1						
AH	2						
EN	2						
FR	2						
GE	2						
IT	2						
RU	2						
TU	2						
AH	3					F	PF, PF
EN	3						
FR	3				FP, F, P	FP, DPF	
GE	3			PF			UNB
IT	3	UP		UNB			UP

RU	3	DF		N	NF	DP	
TU	3						
AH	4				P	FP	PF
EN	4						
FR	4				PF, F	PF	
GE	4			PF			U
IT	4	UP		UN			UP
RU	4	FP		N	UB	PF	
TU	4						
AH	5			UP	UNF	DB	
EN	5						
FR	5	P, PF, DPF			PF	DF, DPF	UB
GE	5	UP				DB	B
IT	5	UNB		UN, UNF			
RU	5	UPB		NB	DN	D	
TU	5						
AH	6						PF
EN	6						
FR	6						
GE	6						PB
IT	6						
RU	6	P		NB	N	D	
TU	6						

AH	7			D		P	
EN	7						
FR	7	DPF, D			PF, DPF	B	PF
GE	7			UB			UB
IT	7	UNF					
RU	7	UB		PB	D	DP	
TU	7						
AH	8						
EN	8						
FR	8				DPF	NB	P, PF
GE	8			UPB			B
IT	8	UP		UB			UP
RU	8	DP		PF	U	U	
TU	8						

Table C.5: Mod-SYMLOG Diplomacy Game 2

Appendix D

Human Vs Human Diplomacy Experiments Mod-Snowdrift

D.1 Mod-SYMLOG Game 1 14/01/19

	AH	EN	FR	GE	IT	RU	TU
Classic	1000	0	1100	1200	1700	2300	0
Modified	950	0	1025	1275	1650	1775	0
Coop	5	0	9	6	7	6	0
H Coop	5	0	8	4	0	2	0
Interactions	7	0	10	12	11	17	0

D.2 Mod-SYMLOG Game 2 14/01/19

	AH	EN	FR	GE	IT	RU	TU
Classic	600	3600	0	1400	0	1900	0
Modified	625	3525	0	1500	0	2000	0
Coop	3	9	0	4	0	16	0
H Coop	2	6	0	2	0	16	0
Interactions	3	15	0	12	0	18	0

D.3 Mod-SYMLOG Game 4 210119

	AH	EN	FR	GE	IT	RU	TU
Classic	2900	3900	2700	3600	1400	2700	0
Modified	3025	3525	2575	3475	1525	2675	0
Coop	13	9	16	13	3	14	0
H Coop	6	5	12	10	1	13	0
Interactions	14	16	21	18	7	15	0

Appendix E

Prototype Group Survey 1st Year Data

ID	Group	Q01->P/N	Q01->U/D	Q01->F/B	Q02->P/N	Q02->U/D	Q02->F/B	Q03->P/N	Q03->U/D	Q03->F/B	Q04->P/N	Q04->U/D	Q04->F/B	Q05->P/N	Q05->U/D	Q05->F/B
153281	GRPa03				5	6	5	9	5	9	9	5	8	9	5	7
153287	GRPa07	1	10	1	4	1	1	10	1	1	1	1	1	10	1	1
150347	GRPa08	5	3	2	7	7	10	5	5	1	6	5	9	5	5	1
152812	GRPa10										10	10	10			
150139	GRPa15	10	5	10	5	5	4	5	6	9	9	5	9			
152790	GRPa26	5	7	4	6	7	5							9	3	10
117907	GRPa29	8	5	8	6	6	5				10	10	10			
151969	GRPa33							3	10	1	8	5	8	10	5	10
153020	GRPa37	6	6	7	6	6	6	8	7	9						
148609	GRPa37	10	10	10	7	2	8	7	5	10						
148590	GRPa41				5	5	3	4	4	4				6	5	4
149815	GRPa43	10	5	10	9	6	9	10	7	10	9	7	8	10	10	10
152416	GRPa44	10	4	10	10	4	10	10	4	10	10	4	10	10	4	10
150498	GRPa45	10	3	6	10	3	9	10	8	10	10	4	9	10	4	10
148628	GRPa45	10	5	10	10	6	10	10	5	10	10	4	10	10	7	10
152550	GRPa49				8	5	8	1	5	1	6	9	4	10	5	10
155954	GRPa49	10	5	10	6		4	1	5	1	10	6	10	10	5	10
155954	GRPa49	10	5	10	10	3	6	3	5	1	10	6	9	5	5	8
151541	GRPa53	10	7	8	10	8	9	10	6	7				10	9	10
151103	GRPa53				10	5	10	8	6	9	5	5	4	8	8	10
117310	GRPa53	10	5	10	10	5	8	10	6	8	10	7	6			
149923	GRPa53	9	4	10				6	5	9	8	4	8	9	5	10

Table E.1: 1st Year Undergraduate Group Raw Input Q1 - Q5

ID	Group	Q06->P/N	Q06->U/D	Q06->F/B	Q07->P/N	Q07->U/D	Q07->F/B	Q08->P/N	Q08->U/D	Q08->F/B	Submitted on:
153281	GRPa03				8	5	8	8	4	8	43781.8888541667
153287	GRPa07	1	1	1							43777.4237847222
150347	GRPa08				8	5	7				43787.4480324074
152812	GRPa10				10	10	10				43776.9060300926
150139	GRPa15	10	5	10							43773.4643981481
152790	GRPa26	7	3	3	8	4	5	7	4	4	43787.4451273148
117907	GRPa29										43773.396400463
151969	GRPa33	10	5	10							43787.5116898148
153020	GRPa37										43784.3936111111
148609	GRPa37										43784.3962152778
148590	GRPa41	8	5	10	5	5	4				43781.5977662037
149815	GRPa43	9	7	9	10	6	10				43776.8191087963
152416	GRPa44	10	4	10	10	4	10				43777.3848032407
150498	GRPa45	5	5	5	10	5	10				43781.6409375
148628	GRPa45	10	4	10	10	5	10				43784.7129861111
152550	GRPa49	3	2	6							43773.4647569444
155954	GRPa49	5	3	4							43774.4530555556
155954	GRPa49	7	2	6							43781.7330787037
151541	GRPa53	10	2	4							43773.4631828704
151103	GRPa53	8	1	5							43773.6787847222
117310	GRPa53	4	3	3							43773.6804976852
149923	GRPa53	10	3	5							43773.6858564815

Table E.2: 1st Year Undergraduate Group Raw Input Q6 - Q8

Appendix F

Mod-Snowdrift Experiment 1 Changelog With Code Snippets

This chapter includes a changelog for the axelrod prisoner's dilemma python competition code to allow it to play mod-snowdrift games instead. Some code snippets are included in the changelog to help clarify the types of changes made to the core code.

F.1 player.py

added action A, L

```
C, L, A, D = Action.C, Action.L, Action.A, Action.D
```

added action A L to def update_history

```
    if move == C:
        player.cooperations += 1
    elif move == L:
        player.cooperations += 1
    elif move == D:
        player.defections += 1
    elif move == A:
        player.defections += 1
```

F.2 actions.py

added action A, L

added action A L to def flip_action

added action A L to def str_to_action

```
def str_to_actions(actions: str) -> tuple:
    """Takes a string like 'CCDD' and returns a
    tuple of the appropriate actions."""
    action_dict = {'C': Actions.C,
                   'D': Actions.D,
                   'L': Actions.L,
                   'A': Actions.A}
```

F.3 action.py

added values C = 4, L = 3, A = 2, D = 1 to class Action

added action A L to def flip

```
def flip(self):
    """Returns the opposite Action."""
    if self == Action.C:
        return Action.D
    if self == Action.D:
        return Action.C
    if self == Action.L:
        return Action.A
    if self == Action.A:
        return Action.L
```

added action A L to def from_char

F.4 _strategy_utils.py

added actions HC, LC, LD, HD

F.5 tournament.py

added action A, L

added combinations of L and A count to def __get_file_objects

```
"CL count", "CA count",
"LC count", "LL count",
"LA count", "LD count",
"AC count", "AL count",
"AA count", "AD count",
"DL count", "DA count",
"CC to C count",    "DC to C count",
"LC to C count",    "AC to C count",
"CD to C count",    "DD to C count",
"LD to C count",    "AD to C count",
"CL to C count",    "DL to C count",
"LL to C count",    "AL to C count",
"CA to C count",    "DA to C count",
"LA to C count",    "AA to C count",
"CC to D count",    "DC to D count",
"LC to D count",    "AC to D count",
```

```
"CD to D count",    "DD to D count",
"LD to D count",    "AD to D count",
"CL to D count",    "DL to D count",
"LL to D count",    "AL to D count",
"CA to D count",    "DA to D count",
"LA to D count",    "AA to D count",
"CC to L count",    "DC to L count",
"LC to L count",    "AC to L count",
"CD to L count",    "DD to L count",
"LD to L count",    "AD to L count",
"CL to L count",    "DL to L count",
"LL to L count",    "AL to L count",
"CA to L count",    "DA to L count",
"LA to L count",    "AA to L count",
"CC to A count",    "DC to A count",
"LC to A count",    "AC to A count",
"CD to A count",    "DD to A count",
"LD to A count",    "AD to A count",
"CL to A count",    "DL to A count",
"LL to A count",    "AL to A count",
"CA to A count",    "DA to A count",
"LA to A count",    "AA to A count",
"Good partner",
```

added combinations of L and A states to def __write_interactions_to_file

```
states = [(C, C), (C, L), (C, A), (C, D), (L, C),
(L, L), (L, A), (L, D), (A, C), (A, L), (A, A),
(A, D), (D, C), (D, L), (D, A), (D, D)]
```

added L and A states to append commands in def __write_interactions_to_file

F.6 result_set.py

added action A, L

added L and A combinations to columns in def __reshape_out

added L and A combinations to def __build_state_distribution

added L and A combinations to def __build_state_to_action_distribution

added L and A combinations to def __build_tasks columns

F.7 interaction_utils.py

added action A, L

added A and L combinations to def compute_normalised_state_to_action_distribution for player

and A and L count to def compute_normalised_state_to_action_distribution for player

F.8 mock_player.py

added action A, L

F.9 game.py

added action A, L

added L and A mapping combinations to def ___init___scores

```
def __init__(self, T: Score = 300, SH: Score = 100,
SL: Score = 150,TT: Score = 125, R: Score = 200,
RH: Score = 175, TH: Score = 250, S: Score = 100,
RL: Score = 225, RR: Score = 150, SS: Score = 175,
TL: Score = 200, PP: Score = 25, PL: Score = 25,
PH: Score = 0, P: Score = 0) -> None:
```

added SH, SL, TT, RH, TH, RL, RR, SS, TL, PP, PL, PH scores to def ___init___

added SH, SL, TT, RH, TH, RL, RR, SS, TL, PP, PL, PH variables to def RPST

added SH, SL, TT, RH, TH, RL, RR, SS, TL, PP, PL, PH variables to def __repr__

F.10 strategy_transformers.py

added action A, L

F.11 match.py

added action A, L

F.12 finite_state_machines.py

added action A, L

F.13 cooperator.py

added action A, L

F.14 cooperator_Soft.py

copy of cooperator

added action A, L

set strategy to return L

added A and L option for tricky cooperator

F.15 defector.py

added action A, L

set strategy to return A

F.16 defector_Soft.py

copy of defector.py

added action A, L

added A and L option for tricky defector

F.17 rand.py

added action A, L

F.18 random_.py

added action A, L

added L and A returns

F.19 titfortat_ModSnowball.py

copy of titfortat.py

added action A, L

added new A and L return options

added new class TitFor2TatsMS with A return option

added new class TwoTitsForTatMS with A return option

added new class SpitefulTitForTatMS with A and L return options

added new class GrimT4TSoft with A and L return options

F.20 AI_torn.py

```

import axelrodEd as axl

def torn(players):
    """
    turns : integer
        The number of turns per match
    repetitions : integer
```

```
        The number of times the round robin should be repeated
    """
    tournament  = axl.Tournament(players, turns=50, repetitions=100)
    results = tournament.play()

    for i in range(0, len(players)):
        print(players[i], results.wins[i])

    for i in range(0, len(players)):
        print(players[i], "&", sum(results.scores[i]))
    # print("players", players)
    # print("results: ", results.wins)
    print()
    #print("payoffs: ", pprint.pprint(results.payoffs))
    print()
    #print("scores: ", results.scores)
    print()

    print("ranked names: ", results.ranked_names)
    print()
    #print(results.state_distribution)

    print("C = Hard Cooperate \n"
        "L = Light Coop \n"
        "A = Light Defect \n"
```

```
        "D = Hard Defect")



    return



def single_match (players, turns):
    print(players)
    match = axl.Match(players, turns)


    print(match.play())
    print(match.scores())
    print(match.summarise())

    return

players = [axl.Random(0.5), axl.Random(0.8),axl.Random(0.2),axl.Defector(), axl.Cooperator(), axl.Cooperator_Soft(),
           axl.TrickyDefector(), axl.TrickyCooperator_Soft(), axl.TrickyCooperator(), axl.Defector_Soft(),
           axl.TrickyDefector_Soft(), axl.TitForTat(), axl.TitForTatMS(),axl.TwoTitsForTat(), axl.TitFor2Tats(),
```

```
            axl.TwoTitsForTatMS(), axl.TitFor2TatsMS(), axl.SpitefulTitForTat(),  axl.CooperatorSpite(),
            axl.GrimT4TSoft(), axl.GrimT4T(), axl.SpitefulTitForTatMS()
            ]

torn(players)



"""
print("reults: ", results.wins)
print()
print("payoffs: ", pprint.pprint(results.payoffs))
print()
print("scores: ", results.scores)
print()

print("ranked names: ", results.ranked_names)
print()

print("C = Hard Cooperate \n"
    "L = Light Coop \n"
    "A = Light Defect \n"
    "D = Hard Defect")

"""
```

```
#print(results.winner())
#print(results.cooperation())

#ummary = results.summarise()
#pprint.pprint(summary)
```

Appendix G

Mod-Snowdrift Experiment 2 Results

G.1 Mod-Snowdrift Experiment 2

Data from mod-Snowdrift experiment 2 with player responses expressed as a python counter (collections.Counter). This is to save space on the table as each player could have up to 7 AI opponents and 50 plays with each.

20200706205253	Spiteful Tit for Tat	Counter((0, 0): 5, (0, 10): 1)
20200706205253	Cooperative	Counter((0, 10): 48, (0, 10): 1)
20200706205253	Tit for Tat	Counter()
20200707104809	Spiteful Tit for Tat	Counter((3, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1, (0, 0): 1, (7, 0): 1)
20200707105119	Defector Light	Counter((10, 3): 1, (3, 3): 1, (10, 3): 1)

20200707105321	Tit for Tat	Counter((0, 0): 3, (0, 10): 1)
20200707105321	Cooperative	Counter((0, 10): 48, (0, 10): 1)
20200707105321	Spiteful Tit for Tat	Counter((0, 10): 1, (0, 0): 1)
20200707105321	Defector	Counter((0, 0): 1, (0, 0): 1)
20200707105321	Defector Light	Counter((0, 3): 7, (0, 3): 1)
20200707105321	Cooperative Spite	Counter((0, 0): 6, (0, 10): 2, (0, 10): 1)
20200707105321	Random	Counter((0, 10): 9, (0, 7): 4, (0, 3): 4, (0, 3): 1, (10, 7): 1)
20200707105321	Cooperative Light	Counter((0, 7): 1, (0, 7): 1)
20200707105405	Spiteful Tit for Tat	Counter((3, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1, (0, 0): 1, (7, 0): 1)
20200707105405	Cooperative	Counter()
20200707105405	Cooperative Spite	Counter((7, 10): 2, (7, 0): 2, (7, 10): 1, (3, 0): 1)
20200707105451	Spiteful Tit for Tat	Counter((3, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1, (0, 0): 1, (7, 0): 1)
20200707105451	Cooperative	Counter()
20200707105451	Cooperative Spite	Counter((7, 10): 2, (7, 0): 2, (7, 10): 1, (3, 0): 1)
20200707105451	Spiteful Tit for Tat	Counter()
20200707105451	Tit for Tat	Counter((7, 7): 3, (3, 3): 3, (0, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1)

20200707105506	Spiteful Tit for Tat	Counter((3, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1, (0, 0): 1, (7, 0): 1)
20200707105506	Cooperative	Counter()
20200707105506	Cooperative Spite	Counter((7, 10): 2, (7, 0): 2, (7, 10): 1, (3, 0): 1)
20200707105506	Spiteful Tit for Tat	Counter()
20200707105506	Tit for Tat	Counter((7, 7): 3, (3, 3): 3, (0, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1)
20200707105506	Cooperative Spite	Counter()
20200707105518	Spiteful Tit for Tat	Counter((3, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1, (0, 0): 1, (7, 0): 1)
20200707105518	Cooperative	Counter()
20200707105518	Cooperative Spite	Counter((7, 10): 2, (7, 0): 2, (7, 10): 1, (3, 0): 1)
20200707105518	Spiteful Tit for Tat	Counter()
20200707105518	Tit for Tat	Counter((7, 7): 3, (3, 3): 3, (0, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1)
20200707105518	Cooperative Spite	Counter()
20200707105518	Defector	Counter((7, 0): 1)
20200707105547	Spiteful Tit for Tat	Counter((3, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1, (0, 0): 1, (7, 0): 1)
20200707105547	Cooperative	Counter()

20200707105547	Cooperative Spite	Counter((7, 10): 2, (7, 0): 2, (7, 10): 1, (3, 0): 1)
20200707105547	Spiteful Tit for Tat	Counter()
20200707105547	Tit for Tat	Counter((7, 7): 3, (3, 3): 3, (0, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1)
20200707105547	Cooperative Spite	Counter()
20200707105547	Defector	Counter((7, 0): 1)
20200707105547	Cooperative Spite	Counter((0, 0): 4, (7, 10): 2, (3, 0): 2, (7, 10): 1)
20200707105822	Cooperative	Counter((10, 10): 44, (0, 10): 3, (3, 10): 1, (7, 10): 1)
20200707105822	Tit for Tat	Counter((10, 10): 39, (10, 7): 2, (7, 7): 2, (7, 10): 1, (7, 10): 1, (3, 10): 1, (10, 3): 1, (0, 10): 1, (10, 0): 1)
20200707105822	Cooperative Light	Counter((0, 7): 18, (7, 7): 7, (7, 7): 1, (3, 7): 1, (10, 7): 1)
20200707105822	Defector	Counter((7, 0): 1, (3, 0): 1, (0, 0): 1)
20200707105822	Cooperative Spite	Counter((10, 0): 4, (0, 0): 3, (10, 10): 2, (3, 10): 1, (3, 0): 1)
20200707105822	Defector Light	Counter((0, 3): 29, (7, 3): 2, (3, 3): 1, (3, 3): 1)
20200707105822	Spiteful Tit for Tat	Counter((10, 3): 3, (0, 0): 3, (3, 0): 3, (3, 10): 1, (7, 3): 1, (0, 3): 1)

20200707105822	Random	Counter((0, 3): 10, (0, 7): 7, (0, 10): 6, (3, 7): 4, (3, 3): 4, (0, 10): 1, (7, 10): 1, (7, 7): 1, (3, 10): 1)
20200707110833	Random	Counter((10, 7): 3, (10, 10): 2, (10, 3): 2, (7, 7): 2, (3, 10): 2, (7, 10): 1, (0, 10): 1)
20200707111714	Random	Counter((10, 7): 11, (10, 10): 10, (10, 3): 8, (7, 10): 5, (7, 3): 4, (3, 10): 4, (3, 3): 3, (3, 7): 2, (3, 7): 1, (7, 7): 1)
20200707111714	Cooperative	Counter((10, 10): 48, (10, 10): 1)
20200707111714	Spiteful Tit for Tat	Counter((7, 7): 45, (10, 7): 3, (7, 10): 1)
20200707111714	Cooperative Light	Counter((7, 7): 43, (3, 7): 3, (10, 7): 2, (7, 7): 1)
20200707111714	Defector	Counter((0, 0): 39, (10, 0): 1)
20200707111714	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200707112251	Cooperative Spite	Counter((0, 0): 12, (3, 0): 5, (3, 10): 1, (0, 10): 1, (3, 10): 1)
20200707112251	Cooperative	Counter((0, 10): 43, (3, 10): 5, (3, 10): 1)
20200707112251	Random	Counter((0, 3): 17, (0, 10): 12, (0, 7): 10, (3, 3): 4, (3, 7): 3, (3, 10): 2, (0, 3): 1)
20200707112251	Tit for Tat	Counter((3, 3): 29, (3, 0): 5, (0, 3): 4, (0, 0): 3, (7, 3): 3, (3, 7): 3, (0, 10): 1, (7, 7): 1)
20200707114249	Defector	Counter((7, 0): 1, (3, 0): 1)

20200707114249	Cooperative Spite	Counter((10, 10): 2, (7, 10): 1, (10, 0): 1, (3, 0): 1)
20200707114249	Random	Counter((10, 10): 1, (10, 3): 1, (7, 7): 1, (7, 3): 1)
20200707114249	Cooperative Light	Counter((7, 7): 48, (10, 7): 1)
20200707114249	Defector Light	Counter((10, 3): 1, (7, 3): 1)
20200707114252	Tit for Tat	Counter((10, 10): 16, (3, 10): 1, (10, 3): 1, (7, 10): 1, (10, 7): 1)
20200707114252	Spiteful Tit for Tat	Counter((7, 7): 12, (10, 7): 4, (7, 3): 2, (7, 10): 1, (3, 7): 1)
20200707114252	Cooperative	Counter((10, 10): 9, (7, 10): 1)
20200707115807	Cooperative Light	Counter((7, 7): 39, (10, 7): 6, (0, 7): 3, (10, 7): 1)
20200707115807	Defector	Counter((0, 0): 3, (10, 0): 1, (3, 0): 1, (10, 0): 1)
20200707115807	Random	Counter((7, 3): 6, (10, 3): 5, (3, 7): 5, (10, 7): 4, (3, 10): 4, (7, 7): 3, (7, 10): 3, (10, 10): 2, (3, 3): 2, (10, 7): 1)
20200707115807	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200707115807	Defector Light	Counter((3, 3): 41, (10, 3): 7, (10, 3): 1)
20200707115807	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200707115807	Cooperative Spite	Counter((0, 0): 4, (10, 10): 2, (10, 0): 2, (10, 10): 1)

20200707115807	Cooperative	Counter((10, 10): 48, (10, 10): 1)
20200707121008	Cooperative Light	Counter()
20200707121008	Cooperative Spite	Counter((7, 10): 1, (7, 10): 1, (10, 10): 1, (10, 0): 1)
20200707121008	Spiteful Tit for Tat	Counter((7, 7): 2, (7, 10): 1)
20200707122935	Random	Counter()
20200707122935	Spiteful Tit for Tat	Counter((10, 10): 3, (10, 10): 1, (0, 10): 1)
20200707122935	Cooperative Light	Counter((7, 7): 7, (0, 7): 7, (10, 7): 1)
20200707125749	Tit for Tat	Counter((0, 0): 4, (7, 7): 3, (10, 10): 2, (7, 10): 1, (3, 7): 1, (7, 3): 1, (10, 7): 1, (0, 10): 1, (7, 0): 1, (0, 7): 1)
20200707125749	Cooperative	Counter((7, 10): 6, (3, 10): 3, (0, 10): 3, (10, 10): 2, (3, 10): 1)
20200707125749	Defector Light	Counter((0, 3): 11, (10, 3): 1, (3, 3): 1, (7, 3): 1)
20200707134831	Random	Counter((0, 10): 3, (0, 7): 2, (0, 3): 1, (0, 3): 1)
20200707140353	Cooperative Spite	Counter()
20200707140353	Defector	Counter((0, 0): 2, (7, 0): 1, (7, 0): 1, (3, 0): 1, (10, 0): 1)
20200707140353	Defector Light	Counter()
20200707140353	Random	Counter((10, 7): 9, (7, 10): 8, (10, 10): 7, (10, 3): 6, (7, 7): 5, (3, 7): 5, (7, 3): 4, (3, 3): 3, (10, 10): 1, (3, 10): 1)

20200707142328	Spiteful Tit for Tat	Counter((3, 3): 9, (7, 3): 6, (7, 7): 4, (7, 10): 1, (10, 7): 1, (3, 7): 1, (10, 3): 1)
20200707142328	Tit for Tat	Counter((7, 7): 19, (10, 10): 5, (10, 7): 2, (7, 10): 2, (7, 10): 1)
20200707142328	Random	Counter((7, 10): 10, (3, 7): 10, (7, 7): 9, (7, 3): 9, (3, 3): 5, (3, 10): 4, (7, 10): 1, (10, 10): 1)
20200707142328	Defector	Counter((10, 0): 1, (7, 0): 1, (3, 0): 1, (0, 0): 1)
20200707142328	Cooperative	Counter((7, 10): 36, (7, 10): 1, (10, 10): 1, (3, 10): 1)
20200707142328	Cooperative Light	Counter((7, 7): 20, (0, 7): 8, (3, 7): 6, (10, 7): 2, (7, 7): 1)
20200707142328	Cooperative Spite	Counter((10, 0): 3, (7, 10): 2, (7, 10): 1, (7, 0): 1, (3, 0): 1, (0, 0): 1)
20200707142328	Defector Light	Counter((3, 3): 8, (7, 3): 4, (0, 3): 3, (7, 3): 1)
20200707143807	Cooperative Light	Counter((7, 7): 17, (3, 7): 8, (10, 7): 5, (7, 7): 1)
20200707143807	Tit for Tat	Counter((7, 7): 16, (10, 10): 15, (10, 7): 2, (7, 10): 2, (3, 3): 2, (7, 10): 1, (3, 7): 1, (7, 3): 1)
20200707143807	Cooperative	Counter((3, 10): 24, (10, 10): 3, (7, 10): 1)
20200707143807	Cooperative Spite	Counter((7, 0): 3, (10, 10): 2, (10, 0): 2, (10, 10): 1)
20200707143807	Spiteful Tit for Tat	Counter((7, 7): 12, (10, 10): 8, (10, 10): 1, (7, 10): 1)

20200707143807	Random	Counter((7, 7): 13, (3, 3): 6, (7, 3): 5, (7, 10): 5, (0, 7): 4, (3, 10): 4, (0, 3): 3, (0, 10): 2, (3, 7): 2, (0, 10): 1, (10, 7): 1)
20200707143807	Defector	Counter((3, 0): 1, (3, 0): 1, (0, 0): 1, (10, 0): 1)
20200707143807	Defector Light	Counter((3, 3): 9, (0, 3): 4, (7, 3): 3, (3, 3): 1, (10, 3): 1)
20200707145522	Cooperative Light	Counter((7, 7): 17, (3, 7): 8, (10, 7): 5, (7, 7): 1)
20200707145522	Tit for Tat	Counter((7, 7): 16, (10, 10): 15, (10, 7): 2, (7, 10): 2, (3, 3): 2, (7, 10): 1, (3, 7): 1, (7, 3): 1)
20200707145522	Cooperative	Counter((3, 10): 24, (10, 10): 3, (7, 10): 1)
20200707145522	Cooperative Spite	Counter((7, 0): 3, (10, 10): 2, (10, 0): 2, (10, 10): 1)
20200707145522	Spiteful Tit for Tat	Counter((7, 7): 12, (10, 10): 8, (10, 10): 1, (7, 10): 1)
20200707145522	Random	Counter((7, 7): 13, (3, 3): 6, (7, 3): 5, (7, 10): 5, (0, 7): 4, (3, 10): 4, (0, 3): 3, (0, 10): 2, (3, 7): 2, (0, 10): 1, (10, 7): 1)
20200707145522	Defector	Counter((3, 0): 1, (3, 0): 1, (0, 0): 1, (10, 0): 1)
20200707145522	Defector Light	Counter((3, 3): 9, (0, 3): 4, (7, 3): 3, (3, 3): 1, (10, 3): 1)
20200707145522	Cooperative Spite	Counter((10, 0): 4, (0, 0): 3, (10, 10): 2, (3, 0): 2, (10, 10): 1)

20200707145522	Tit for Tat	Counter((7, 7): 19, (10, 10): 8, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1, (7, 10): 1)
20200707145522	Cooperative	Counter((10, 10): 40, (7, 10): 5, (3, 10): 3, (3, 10): 1)
20200707145522	Spiteful Tit for Tat	Counter((3, 0): 2, (0, 10): 1, (0, 0): 1, (7, 0): 1)
20200707145522	Defector	Counter((10, 0): 1, (7, 0): 1, (3, 0): 1)
20200707145522	Random	Counter((3, 3): 9, (7, 3): 7, (3, 10): 7, (7, 7): 7, (7, 10): 7, (3, 7): 3, (0, 10): 2, (10, 7): 2, (3, 10): 1, (10, 10): 1, (10, 3): 1, (0, 7): 1, (0, 3): 1)
20200707145522	Cooperative Light	Counter((7, 7): 19, (0, 7): 10, (3, 7): 8, (10, 7): 2, (10, 7): 1)
20200707145522	Defector Light	Counter((0, 3): 11, (3, 3): 2, (7, 3): 2, (3, 3): 1, (10, 3): 1)
20200707162842	Cooperative Light	Counter((7, 7): 29, (0, 7): 18, (7, 7): 1, (3, 7): 1)
20200707190627	Defector Light	Counter((0, 3): 14, (3, 3): 5, (0, 3): 1, (10, 3): 1)
20200707190627	Cooperative Light	Counter((3, 7): 10, (0, 7): 8, (7, 7): 4, (3, 7): 1, (10, 7): 1)
20200707190627	Spiteful Tit for Tat	Counter((3, 3): 3, (0, 0): 2, (3, 10): 1, (7, 3): 1, (0, 3): 1, (3, 0): 1, (7, 0): 1)

20200707190627	Cooperative Spite	Counter((10, 10): 2, (0, 0): 2, (3, 0): 2, (10, 10): 1, (10, 0): 1)
20200707190627	Tit for Tat	Counter((7, 7): 16, (10, 10): 5, (3, 3): 5, (3, 7): 2, (7, 3): 2, (10, 10): 1, (7, 10): 1)
20200707190627	Random	Counter((0, 3): 6, (0, 10): 6, (3, 10): 5, (3, 7): 4, (0, 7): 4, (7, 7): 3, (7, 10): 3, (10, 3): 2, (7, 3): 2, (3, 3): 1, (10, 10): 1, (3, 3): 1)
20200707190627	Cooperative	Counter((7, 10): 18, (10, 10): 3, (7, 10): 1)
20200707201248	Defector Light	Counter((0, 3): 40, (3, 3): 7, (10, 3): 1, (7, 3): 1)
20200707204212	Random	Counter((7, 7): 2, (7, 7): 1, (10, 3): 1, (0, 10): 1, (3, 7): 1, (10, 7): 1)
20200707213038	Cooperative Spite	Counter((0, 10): 2, (0, 0): 2, (0, 10): 1)
20200707213038	Cooperative	Counter((7, 10): 33, (0, 10): 13, (10, 10): 2, (0, 10): 1)
20200707213038	Defector	Counter()
20200707213038	Defector Light	Counter((0, 3): 48, (7, 3): 1)
20200707215014	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200707215014	Cooperative Spite	Counter((3, 0): 4, (7, 0): 3, (10, 10): 2, (10, 10): 1, (10, 0): 1)
20200707215014	Cooperative Light	Counter((7, 7): 45, (10, 7): 3, (7, 7): 1)
20200707215014	Random	Counter((7, 7): 12, (7, 10): 10, (7, 3): 8, (10, 7): 7, (10, 10): 6, (10, 3): 5, (10, 7): 1)

20200707215014	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200707223716	Defector	Counter()
20200707223716	Cooperative Light	Counter((7, 7): 48, (7, 7): 1)
20200707223716	Cooperative	Counter((10, 10): 46, (3, 10): 2, (10, 10): 1)
20200707223716	Spiteful Tit for Tat	Counter((10, 0): 41, (0, 0): 3, (3, 0): 2, (7, 0): 2, (0, 10): 1)
20200707230836	Cooperative	Counter((10, 10): 42, (7, 10): 6, (10, 10): 1)
20200707230836	Tit for Tat	Counter((10, 10): 41, (7, 7): 5, (10, 10): 1, (7, 10): 1, (10, 7): 1)
20200707230836	Defector	Counter((10, 0): 1, (7, 0): 1, (3, 0): 1, (0, 0): 1)
20200707230836	Cooperative Light	Counter((7, 7): 32, (0, 7): 7, (3, 7): 5, (10, 7): 4, (10, 7): 1)
20200707230836	Random	Counter((10, 7): 4, (7, 3): 3, (7, 10): 3, (10, 10): 2, (3, 3): 2, (3, 10): 2, (10, 10): 1, (10, 3): 1, (7, 7): 1, (3, 7): 1, (0, 3): 1)
20200707230836	Defector Light	Counter((3, 3): 1, (7, 3): 1, (10, 3): 1, (0, 3): 1, (3, 3): 1)
20200707230836	Cooperative Spite	Counter((3, 0): 2, (7, 10): 1, (7, 10): 1, (10, 10): 1, (10, 0): 1)
20200707230836	Spiteful Tit for Tat	Counter((7, 7): 5, (10, 7): 2, (7, 10): 1, (3, 7): 1, (3, 3): 1, (10, 3): 1)
20200707235105	Cooperative Light	Counter((7, 7): 14, (3, 7): 14, (0, 7): 11, (10, 7): 9, (10, 7): 1)

20200708080452	Random	Counter((7, 3): 14, (7, 10): 14, (7, 7): 8, (10, 3): 7, (10, 10): 4, (7, 10): 1, (10, 7): 1)
20200708080452	Cooperative Spite	Counter((7, 0): 11, (7, 10): 2, (0, 0): 2, (7, 10): 1)
20200708084128	Spiteful Tit for Tat	Counter((7, 7): 48, (7, 10): 1)
20200708084128	Cooperative Spite	Counter((10, 10): 2, (7, 10): 1, (10, 0): 1, (3, 0): 1)
20200708084128	Random	Counter((3, 10): 12, (3, 3): 9, (3, 7): 9, (0, 3): 4, (10, 10): 3, (7, 3): 3, (7, 7): 2, (0, 7): 2, (0, 10): 2, (7, 7): 1, (7, 10): 1, (10, 3): 1)
20200708084128	Tit for Tat	Counter((7, 7): 25, (10, 10): 20, (10, 7): 2, (7, 10): 1, (7, 10): 1)
20200708084128	Cooperative Light	Counter((7, 7): 44, (10, 7): 2, (3, 7): 2, (7, 7): 1)
20200708090248	Cooperative Spite	Counter((10, 10): 2, (0, 0): 2, (7, 10): 1, (10, 0): 1, (3, 0): 1)
20200708090248	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200708090248	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200708090248	Defector	Counter((0, 0): 2, (10, 0): 1, (7, 0): 1)
20200708090248	Cooperative Light	Counter((7, 7): 47, (10, 7): 1, (10, 7): 1)
20200708090248	Random	Counter((7, 3): 9, (10, 7): 8, (10, 10): 7, (7, 7): 6, (3, 10): 6, (3, 3): 5, (3, 7): 4, (10, 3): 2, (10, 7): 1, (7, 10): 1)

20200708090248	Defector Light	Counter((3, 3): 47, (10, 3): 1, (7, 3): 1)
20200708090248	Cooperative	Counter((10, 10): 48, (10, 10): 1)
20200708123040	Cooperative Light	Counter((7, 7): 13, (10, 7): 7, (0, 7): 6, (3, 7): 5, (10, 7): 1)
20200708123040	Random	Counter((10, 3): 5, (10, 7): 2, (10, 3): 1, (10, 10): 1, (7, 7): 1)
20200708123040	Defector	Counter((10, 0): 3, (0, 0): 3, (3, 0): 2, (10, 0): 1, (7, 0): 1)
20200708123040	Tit for Tat	Counter((10, 10): 9, (10, 10): 1)
20200708123040	Spiteful Tit for Tat	Counter((10, 10): 5, (10, 7): 3, (10, 10): 1, (7, 10): 1, (7, 7): 1)
20200708123040	Cooperative	Counter((10, 10): 18, (10, 10): 1, (0, 10): 1)
20200708123040	Cooperative Spite	Counter((10, 0): 9, (10, 10): 2, (10, 10): 1)
20200708123040	Defector Light	Counter((10, 3): 5, (7, 3): 4, (10, 3): 1)
20200708124658	Cooperative Light	Counter((7, 7): 5, (3, 7): 2, (10, 7): 2, (10, 7): 1)
20200708124658	Random	Counter()
20200708124658	Defector Light	Counter((3, 3): 5, (10, 3): 1)
20200708124658	Cooperative	Counter()
20200708124658	Tit for Tat	Counter((10, 10): 6, (10, 10): 1)
20200708124658	Cooperative Spite	Counter((10, 10): 2, (10, 0): 2, (10, 10): 1, (0, 0): 1)
20200708124658	Defector	Counter((10, 0): 1, (0, 0): 1)

20200708124658	Spiteful Tit for Tat	Counter((10, 10): 6, (10, 10): 1)
20200708131846	Defector	Counter()
20200708131846	Spiteful Tit for Tat	Counter((10, 10): 1)
20200708131846	Tit for Tat	Counter((7, 10): 1, (3, 7): 1, (0, 3): 1, (3, 0): 1, (7, 3): 1)
20200708133147	Cooperative	Counter((10, 10): 10, (10, 10): 1)
20200708133147	Cooperative Spite	Counter((10, 10): 2, (10, 10): 1, (10, 0): 1, (0, 0): 1)
20200708133147	Tit for Tat	Counter((10, 10): 7, (10, 10): 1)
20200708133147	Defector	Counter((10, 0): 1, (0, 0): 1)
20200708133147	Random	Counter((7, 10): 2, (10, 10): 2, (10, 3): 2, (10, 3): 1, (3, 7): 1, (10, 7): 1, (3, 10): 1)
20200708133147	Spiteful Tit for Tat	Counter((10, 10): 8, (10, 10): 1)
20200708133147	Cooperative Light	Counter((7, 7): 3, (10, 7): 1, (10, 7): 1)
20200708133147	Defector Light	Counter((3, 3): 2, (10, 3): 1)
20200708143106	Cooperative	Counter((10, 10): 47, (3, 10): 1, (7, 10): 1)
20200708143106	Defector	Counter((0, 0): 8, (7, 0): 1, (7, 0): 1, (3, 0): 1)
20200708143106	Random	Counter((10, 7): 10, (10, 3): 9, (7, 10): 6, (0, 10): 6, (7, 3): 5, (0, 3): 3, (3, 7): 2, (10, 10): 2, (0, 7): 2, (7, 7): 1, (7, 7): 1, (3, 3): 1, (3, 10): 1)
20200708143106	Tit for Tat	Counter()

20200708143106	Cooperative Spite	Counter((0, 0): 16, (10, 10): 2, (10, 10): 1, (10, 0): 1, (7, 0): 1, (3, 0): 1)
20200708143106	Defector Light	Counter()
20200708143106	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200708143106	Cooperative Light	Counter((7, 7): 46, (10, 7): 2, (7, 7): 1, : 1)
20200708150235	Cooperative Spite	Counter((10, 10): 2, (7, 10): 1, (10, 0): 1, (7, 0): 1, (0, 0): 1)
20200708150235	Tit for Tat	Counter((10, 10): 42, (10, 7): 3, (7, 10): 2, (7, 10): 1, (7, 7): 1)
20200708150235	Defector Light	Counter((0, 3): 46, (7, 3): 2, (3, 3): 1)
20200708150235	Random	Counter((0, 3): 10, (0, 7): 9, (3, 7): 8, (0, 10): 8, (3, 3): 4, (3, 10): 4, (7, 10): 3, (10, 10): 1, (10, 3): 1, (7, 3): 1)
20200708150235	Defector	Counter((3, 0): 2, (7, 0): 1, (0, 0): 1)
20200708150235	Cooperative	Counter((0, 10): 37, (10, 10): 5, (7, 10): 3, (3, 10): 3, (7, 10): 1)
20200708150235	Cooperative Light	Counter((0, 7): 38, (3, 7): 8, (7, 7): 2, (10, 7): 1)
20200708155709	Cooperative Spite	Counter((10, 10): 2, (3, 0): 2, (7, 10): 1, (10, 0): 1)
20200708155709	Spiteful Tit for Tat	Counter((7, 7): 7, (10, 7): 5, (10, 0): 3, (7, 10): 1, (0, 7): 1, (0, 0): 1)

20200708155709	Tit for Tat	Counter((10, 10): 9, (3, 3): 3, (3, 10): 2, (10, 3): 2, (0, 10): 2, (0, 0): 2, (7, 7): 2, (3, 0): 2, (10, 10): 1, (7, 10): 1, (10, 7): 1, (7, 0): 1, (0, 7): 1, (10, 0): 1, (0, 3): 1)
20200708162206	Cooperative Spite	Counter()
20200708162206	Defector	Counter((0, 0): 6, (7, 0): 2, (10, 0): 1, (10, 0): 1)
20200708162206	Spiteful Tit for Tat	Counter((10, 10): 5, (10, 10): 1)
20200708162206	Random	Counter((7, 10): 2, (10, 7): 1, (10, 3): 1, (7, 3): 1, (3, 7): 1, (7, 7): 1, (10, 7): 1)
20200708162206	Cooperative	Counter((10, 10): 5, (10, 10): 1)
20200708162206	Defector Light	Counter((3, 3): 4, (10, 3): 2, (10, 3): 1, (7, 3): 1)
20200708162949	Defector	Counter((7, 0): 2, (0, 0): 2, (10, 0): 1, (10, 0): 1)
20200708162949	Defector Light	Counter((3, 3): 3, (10, 3): 1, (10, 3): 1, (7, 3): 1)
20200708162949	Cooperative	Counter((10, 10): 5, (10, 10): 1)
20200708162949	Cooperative Spite	Counter((10, 10): 2, (10, 0): 2, (0, 0): 2, (10, 10): 1, (7, 0): 1)
20200708162949	Random	Counter((10, 10): 3, (10, 3): 2, (7, 3): 2, (10, 10): 1, (7, 10): 1, (10, 7): 1, (7, 7): 1)
20200708162949	Spiteful Tit for Tat	Counter((10, 10): 3, (10, 10): 1)

20200708164654	Cooperative	Counter((10, 10): 7, (7, 10): 3, (7, 10): 1)
20200708164654	Defector Light	Counter((7, 3): 2, (7, 3): 1, (10, 3): 1, (0, 3): 1)
20200708164654	Cooperative Spite	Counter((7, 0): 2, (7, 10): 1, (7, 10): 1, (10, 10): 1, (10, 0): 1, (3, 0): 1)
20200708164654	Random	Counter((7, 10): 2, (7, 3): 2, (10, 7): 2, (7, 3): 1, (7, 7): 1, (10, 10): 1, (10, 3): 1)
20200708185209	Cooperative Spite	Counter((10, 10): 2, (10, 10): 1, (10, 0): 1)
20200708185209	Cooperative	Counter((10, 10): 31, (10, 10): 1)
20200708185209	Tit for Tat	Counter((10, 10): 21, (10, 10): 1)
20200708185209	Defector	Counter((10, 0): 1)
20200708185209	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200708190455	Random	Counter((7, 7): 7, (7, 10): 6, (3, 10): 4, (3, 7): 3, (7, 3): 3, (10, 3): 3, (3, 3): 2, (10, 7): 2, (3, 10): 1)
20200708190455	Defector	Counter((3, 0): 2, (7, 0): 1, (0, 0): 1)
20200708190455	Spiteful Tit for Tat	Counter((7, 7): 25, (10, 10): 19, (10, 7): 3, (10, 10): 1, (7, 10): 1)
20200708190455	Cooperative Spite	Counter((10, 0): 5, (10, 10): 2, (7, 0): 2, (10, 10): 1, (3, 0): 1)
20200708190455	Cooperative	Counter((10, 10): 22, (3, 10): 3, (0, 10): 3, (7, 10): 2, (10, 10): 1)
20200708190455	Tit for Tat	Counter((10, 10): 32, (7, 7): 10, (7, 10): 3, (10, 7): 3, (10, 10): 1)

20200708190455	Defector Light	Counter((3, 3): 8, (7, 3): 2, (0, 3): 2, (7, 3): 1, (10, 3): 1)
20200708190455	Cooperative Light	Counter((0, 7): 9, (7, 7): 5, (3, 7): 4, (3, 7): 1)
20200708192407	Defector	Counter((10, 0): 1, (10, 0): 1)
20200708192407	Cooperative	Counter((10, 10): 24, (3, 10): 12, (7, 10): 6, (0, 10): 6, (10, 10): 1)
20200708192701	Defector	Counter((10, 0): 1, (10, 0): 1)
20200708192701	Cooperative	Counter((10, 10): 24, (3, 10): 12, (7, 10): 6, (0, 10): 6, (10, 10): 1)
20200708192701	Cooperative	Counter((10, 10): 28, (7, 10): 10, (0, 10): 10, (7, 10): 1)
20200708192900	Defector	Counter((10, 0): 1, (10, 0): 1)
20200708192900	Cooperative	Counter((10, 10): 24, (3, 10): 12, (7, 10): 6, (0, 10): 6, (10, 10): 1)
20200708192900	Cooperative	Counter((10, 10): 28, (7, 10): 10, (0, 10): 10, (7, 10): 1)
20200708192900	Cooperative Spite	Counter((0, 0): 19, (3, 0): 16, (10, 0): 9, (10, 10): 2, (7, 0): 2, (10, 10): 1)
20200708193032	Defector	Counter((10, 0): 1, (10, 0): 1)
20200708193032	Cooperative	Counter((10, 10): 24, (3, 10): 12, (7, 10): 6, (0, 10): 6, (10, 10): 1)
20200708193032	Cooperative	Counter((10, 10): 28, (7, 10): 10, (0, 10): 10, (7, 10): 1)

20200708193032	Cooperative Spite	Counter({(0, 0): 19, (3, 0): 16, (10, 0): 9, (10, 10): 2, (7, 0): 2, (10, 10): 1})
20200708193032	Cooperative Light	Counter({(3, 7): 25, (10, 7): 8, (0, 7): 8, (7, 7): 7, (10, 7): 1})
20200709152629	Cooperative	Counter({(10, 10): 48, (7, 10): 1})
20200709152826	Cooperative	Counter({(10, 10): 48, (7, 10): 1})
20200709152826	Spiteful Tit for Tat	Counter({(7, 7): 47, (7, 10): 1, (10, 7): 1})
20200709153319	Cooperative	Counter({(10, 10): 48, (7, 10): 1})
20200709153319	Spiteful Tit for Tat	Counter({(7, 7): 47, (7, 10): 1, (10, 7): 1})
20200709153319	Defector Light	Counter({(0, 3): 48, (0, 3): 1})
20200709153719	Cooperative	Counter({(10, 10): 48, (7, 10): 1})
20200709153719	Spiteful Tit for Tat	Counter({(7, 7): 47, (7, 10): 1, (10, 7): 1})
20200709153719	Defector Light	Counter({(0, 3): 48, (0, 3): 1})
20200709153719	Cooperative Spite	Counter()
20200709153719	Tit for Tat	Counter({(10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1})
20200709154117	Cooperative	Counter({(10, 10): 48, (7, 10): 1})
20200709154117	Spiteful Tit for Tat	Counter({(7, 7): 47, (7, 10): 1, (10, 7): 1})
20200709154117	Defector Light	Counter({(0, 3): 48, (0, 3): 1})
20200709154117	Cooperative Spite	Counter()

20200709154117	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)
20200709154117	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709154338	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709154338	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709154338	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709154338	Cooperative Spite	Counter()
20200709154338	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)
20200709154338	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709154338	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709154641	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709154641	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709154641	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709154641	Cooperative Spite	Counter()
20200709154641	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)

20200709154641	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709154641	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709154641	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709154924	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709154924	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709154924	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709154924	Cooperative Spite	Counter()
20200709154924	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)
20200709154924	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709154924	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709154924	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709154924	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709155355	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709155355	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709155355	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709155355	Cooperative Spite	Counter()
20200709155355	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)

20200709155355	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709155355	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709155355	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709155355	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709155355	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709155703	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709155703	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709155703	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709155703	Cooperative Spite	Counter()
20200709155703	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)
20200709155703	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709155703	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709155703	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709155703	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709155703	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709155703	Defector Light	Counter((3, 3): 26, (0, 3): 17, (10, 3): 5, (10, 3): 1)

20200709155955	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709155955	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709155955	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709155955	Cooperative Spite	Counter()
20200709155955	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)
20200709155955	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709155955	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709155955	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709155955	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709155955	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709155955	Defector Light	Counter((3, 3): 26, (0, 3): 17, (10, 3): 5, (10, 3): 1)
20200709155955	Defector Light	Counter((3, 3): 32, (0, 3): 15, (10, 3): 1, (10, 3): 1)
20200709160234	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709160234	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709160234	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709160234	Cooperative Spite	Counter()

20200709160234	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)
20200709160234	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709160234	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709160234	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709160234	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709160234	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709160234	Defector Light	Counter((3, 3): 26, (0, 3): 17, (10, 3): 5, (10, 3): 1)
20200709160234	Defector Light	Counter((3, 3): 32, (0, 3): 15, (10, 3): 1, (10, 3): 1)
20200709160234	Cooperative Light	Counter((7, 7): 43, (0, 7): 3, (10, 7): 1, (10, 7): 1, (3, 7): 1)
20200709160506	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709160506	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709160506	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709160506	Cooperative Spite	Counter()
20200709160506	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)

20200709160506	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709160506	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709160506	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709160506	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709160506	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709160506	Defector Light	Counter((3, 3): 26, (0, 3): 17, (10, 3): 5, (10, 3): 1)
20200709160506	Defector Light	Counter((3, 3): 32, (0, 3): 15, (10, 3): 1, (10, 3): 1)
20200709160506	Cooperative Light	Counter((7, 7): 43, (0, 7): 3, (10, 7): 1, (10, 7): 1, (3, 7): 1)
20200709160506	Defector Light	Counter((3, 3): 25, (0, 3): 16, (10, 3): 4, (7, 3): 3, (10, 3): 1)
20200709160720	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709160720	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709160720	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709160720	Cooperative Spite	Counter()
20200709160720	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)

20200709160720	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709160720	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709160720	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709160720	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709160720	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709160720	Defector Light	Counter((3, 3): 26, (0, 3): 17, (10, 3): 5, (10, 3): 1)
20200709160720	Defector Light	Counter((3, 3): 32, (0, 3): 15, (10, 3): 1, (10, 3): 1)
20200709160720	Cooperative Light	Counter((7, 7): 43, (0, 7): 3, (10, 7): 1, (10, 7): 1, (3, 7): 1)
20200709160720	Defector Light	Counter((3, 3): 25, (0, 3): 16, (10, 3): 4, (7, 3): 3, (10, 3): 1)
20200709160720	Cooperative Light	Counter((7, 7): 48, (0, 7): 1)
20200709161044	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709161044	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709161044	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709161044	Cooperative Spite	Counter()
20200709161044	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)

20200709161044	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709161044	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709161044	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709161044	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709161044	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709161044	Defector Light	Counter((3, 3): 26, (0, 3): 17, (10, 3): 5, (10, 3): 1)
20200709161044	Defector Light	Counter((3, 3): 32, (0, 3): 15, (10, 3): 1, (10, 3): 1)
20200709161044	Cooperative Light	Counter((7, 7): 43, (0, 7): 3, (10, 7): 1, (10, 7): 1, (3, 7): 1)
20200709161044	Defector Light	Counter((3, 3): 25, (0, 3): 16, (10, 3): 4, (7, 3): 3, (10, 3): 1)
20200709161044	Cooperative Light	Counter((7, 7): 48, (0, 7): 1)
20200709161044	Random	Counter((7, 7): 13, (7, 3): 9, (3, 7): 7, (7, 10): 5, (3, 3): 4, (10, 7): 3, (10, 3): 2, (0, 7): 2, (10, 10): 2, (0, 3): 1, (3, 10): 1)
20200709161240	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709161240	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709161240	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709161240	Cooperative Spite	Counter()

20200709161240	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)
20200709161240	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709161240	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709161240	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709161240	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709161240	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709161240	Defector Light	Counter((3, 3): 26, (0, 3): 17, (10, 3): 5, (10, 3): 1)
20200709161240	Defector Light	Counter((3, 3): 32, (0, 3): 15, (10, 3): 1, (10, 3): 1)
20200709161240	Cooperative Light	Counter((7, 7): 43, (0, 7): 3, (10, 7): 1, (10, 7): 1, (3, 7): 1)
20200709161240	Defector Light	Counter((3, 3): 25, (0, 3): 16, (10, 3): 4, (7, 3): 3, (10, 3): 1)
20200709161240	Cooperative Light	Counter((7, 7): 48, (0, 7): 1)
20200709161240	Random	Counter((7, 7): 13, (7, 3): 9, (3, 7): 7, (7, 10): 5, (3, 3): 4, (10, 7): 3, (10, 3): 2, (0, 7): 2, (10, 10): 2, (0, 3): 1, (3, 10): 1)

20200709161240	Tit for Tat	Counter((10, 10): 44, (3, 3): 3, (3, 10): 1, (10, 3): 1)
20200709161456	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709161456	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709161456	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709161456	Cooperative Spite	Counter()
20200709161456	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)
20200709161456	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709161456	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709161456	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709161456	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709161456	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709161456	Defector Light	Counter((3, 3): 26, (0, 3): 17, (10, 3): 5, (10, 3): 1)
20200709161456	Defector Light	Counter((3, 3): 32, (0, 3): 15, (10, 3): 1, (10, 3): 1)
20200709161456	Cooperative Light	Counter((7, 7): 43, (0, 7): 3, (10, 7): 1, (10, 7): 1, (3, 7): 1)

20200709161456	Defector Light	Counter((3, 3): 25, (0, 3): 16, (10, 3): 4, (7, 3): 3, (10, 3): 1)
20200709161456	Cooperative Light	Counter((7, 7): 48, (0, 7): 1)
20200709161456	Random	Counter((7, 7): 13, (7, 3): 9, (3, 7): 7, (7, 10): 5, (3, 3): 4, (10, 7): 3, (10, 3): 2, (0, 7): 2, (10, 10): 2, (0, 3): 1, (3, 10): 1)
20200709161456	Tit for Tat	Counter((10, 10): 44, (3, 3): 3, (3, 10): 1, (10, 3): 1)
20200709161456	Tit for Tat	Counter((7, 7): 16, (0, 0): 10, (10, 10): 10, (3, 3): 6, (10, 0): 2, (7, 10): 2, (0, 10): 1, (3, 7): 1, (0, 3): 1)
20200709161708	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709161708	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709161708	Defector Light	Counter((0, 3): 48, (0, 3): 1)
20200709161708	Cooperative Spite	Counter()
20200709161708	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)
20200709161708	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709161708	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709161708	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709161708	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)

20200709161708	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709161708	Defector Light	Counter((3, 3): 26, (0, 3): 17, (10, 3): 5, (10, 3): 1)
20200709161708	Defector Light	Counter((3, 3): 32, (0, 3): 15, (10, 3): 1, (10, 3): 1)
20200709161708	Cooperative Light	Counter((7, 7): 43, (0, 7): 3, (10, 7): 1, (10, 7): 1, (3, 7): 1)
20200709161708	Defector Light	Counter((3, 3): 25, (0, 3): 16, (10, 3): 4, (7, 3): 3, (10, 3): 1)
20200709161708	Cooperative Light	Counter((7, 7): 48, (0, 7): 1)
20200709161708	Random	Counter((7, 7): 13, (7, 3): 9, (3, 7): 7, (7, 10): 5, (3, 3): 4, (10, 7): 3, (10, 3): 2, (0, 7): 2, (10, 10): 2, (0, 3): 1, (3, 10): 1)
20200709161708	Tit for Tat	Counter((10, 10): 44, (3, 3): 3, (3, 10): 1, (10, 3): 1)
20200709161708	Tit for Tat	Counter((7, 7): 16, (0, 0): 10, (10, 10): 10, (3, 3): 6, (10, 0): 2, (7, 10): 2, (0, 10): 1, (3, 7): 1, (0, 3): 1)
20200709161708	Defector Light	Counter((3, 3): 42, (0, 3): 4, (7, 3): 2, (7, 3): 1)
20200709161927	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709161927	Spiteful Tit for Tat	Counter((7, 7): 47, (7, 10): 1, (10, 7): 1)
20200709161927	Defector Light	Counter((0, 3): 48, (0, 3): 1)

20200709161927	Cooperative Spite	Counter()
20200709161927	Tit for Tat	Counter((10, 10): 19, (7, 7): 14, (3, 3): 11, (3, 10): 1, (10, 3): 1, (3, 10): 1, (7, 3): 1, (10, 7): 1)
20200709161927	Spiteful Tit for Tat	Counter((10, 10): 29, (7, 7): 18, (10, 10): 1, (7, 10): 1)
20200709161927	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709161927	Defector Light	Counter((0, 3): 39, (3, 3): 7, (7, 3): 2, (3, 3): 1)
20200709161927	Cooperative	Counter((7, 10): 47, (10, 10): 1, (10, 10): 1)
20200709161927	Cooperative Spite	Counter((0, 0): 23, (3, 0): 13, (7, 0): 7, (10, 0): 3, (0, 10): 2, (0, 10): 1)
20200709161927	Defector Light	Counter((3, 3): 26, (0, 3): 17, (10, 3): 5, (10, 3): 1)
20200709161927	Defector Light	Counter((3, 3): 32, (0, 3): 15, (10, 3): 1, (10, 3): 1)
20200709161927	Cooperative Light	Counter((7, 7): 43, (0, 7): 3, (10, 7): 1, (10, 7): 1, (3, 7): 1)
20200709161927	Defector Light	Counter((3, 3): 25, (0, 3): 16, (10, 3): 4, (7, 3): 3, (10, 3): 1)
20200709161927	Cooperative Light	Counter((7, 7): 48, (0, 7): 1)
20200709161927	Random	Counter((7, 7): 13, (7, 3): 9, (3, 7): 7, (7, 10): 5, (3, 3): 4, (10, 7): 3, (10, 3): 2, (0, 7): 2, (10, 10): 2, (0, 3): 1, (3, 10): 1)

20200709161927	Tit for Tat	Counter((10, 10): 44, (3, 3): 3, (3, 10): 1, (10, 3): 1)
20200709161927	Tit for Tat	Counter((7, 7): 16, (0, 0): 10, (10, 10): 10, (3, 3): 6, (10, 0): 2, (7, 10): 2, (0, 10): 1, (3, 7): 1, (0, 3): 1)
20200709161927	Defector Light	Counter((3, 3): 42, (0, 3): 4, (7, 3): 2, (7, 3): 1)
20200709161927	Cooperative Light	Counter((7, 7): 46, (0, 7): 2, (0, 7): 1)
20200709161949	Cooperative Spite	Counter((10, 10): 2, (7, 10): 1, (10, 0): 1, (7, 0): 1)
20200709161949	Tit for Tat	Counter((10, 10): 47, (7, 10): 1, (10, 7): 1)
20200709161949	Spiteful Tit for Tat	Counter((7, 7): 46, (10, 7): 2, (7, 10): 1)
20200709161949	Defector	Counter((0, 0): 2, (10, 0): 1)
20200709161949	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709161949	Defector Light	Counter()
20200709161949	Random	Counter((3, 7): 11, (3, 3): 10, (3, 10): 8, (7, 3): 5, (10, 3): 4, (10, 7): 3, (7, 7): 3, (10, 10): 2, (7, 10): 2, (10, 10): 1)
20200709161949	Cooperative Light	Counter()
20200709175147	Cooperative Spite	Counter((10, 10): 2, (7, 10): 1, (10, 0): 1, (7, 0): 1)
20200709175147	Tit for Tat	Counter((10, 10): 47, (7, 10): 1, (10, 7): 1)
20200709175147	Spiteful Tit for Tat	Counter((7, 7): 46, (10, 7): 2, (7, 10): 1)
20200709175147	Defector	Counter((0, 0): 2, (10, 0): 1)

20200709175147	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709175147	Defector Light	Counter()
20200709175147	Random	Counter((3, 7): 11, (3, 3): 10, (3, 10): 8, (7, 3): 5, (10, 3): 4, (10, 7): 3, (7, 7): 3, (10, 10): 2, (7, 10): 2, (10, 10): 1)
20200709175147	Cooperative Light	Counter()
20200709175147	Cooperative Spite	Counter()
20200709175147	Random	Counter((7, 7): 10, (7, 3): 8, (7, 10): 8, (10, 7): 5, (10, 10): 5, (3, 10): 4, (3, 7): 4, (3, 3): 3, (10, 7): 1, (10, 3): 1)
20200709175147	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709175147	Defector	Counter((0, 0): 4, (10, 0): 1, (3, 0): 1)
20200709175147	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709175147	Cooperative Light	Counter((0, 7): 26, (7, 7): 18, (3, 7): 4, (10, 7): 1)
20200709175147	Defector Light	Counter((3, 3): 45, (0, 3): 3, (10, 3): 1)
20200709175147	Cooperative	Counter()
20200709180116	Cooperative Spite	Counter((10, 10): 2, (7, 10): 1, (10, 0): 1, (7, 0): 1)
20200709180116	Tit for Tat	Counter((10, 10): 47, (7, 10): 1, (10, 7): 1)
20200709180116	Spiteful Tit for Tat	Counter((7, 7): 46, (10, 7): 2, (7, 10): 1)
20200709180116	Defector	Counter((0, 0): 2, (10, 0): 1)
20200709180116	Cooperative	Counter((10, 10): 48, (7, 10): 1)

20200709180116	Defector Light	Counter()
20200709180116	Random	Counter((3, 7): 11, (3, 3): 10, (3, 10): 8, (7, 3): 5, (10, 3): 4, (10, 7): 3, (7, 7): 3, (10, 10): 2, (7, 10): 2, (10, 10): 1)
20200709180116	Cooperative Light	Counter()
20200709180116	Cooperative Spite	Counter()
20200709180116	Random	Counter((7, 7): 10, (7, 3): 8, (7, 10): 8, (10, 7): 5, (10, 10): 5, (3, 10): 4, (3, 7): 4, (3, 3): 3, (10, 7): 1, (10, 3): 1)
20200709180116	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709180116	Defector	Counter((0, 0): 4, (10, 0): 1, (3, 0): 1)
20200709180116	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709180116	Cooperative Light	Counter((0, 7): 26, (7, 7): 18, (3, 7): 4, (10, 7): 1)
20200709180116	Defector Light	Counter((3, 3): 45, (0, 3): 3, (10, 3): 1)
20200709180116	Cooperative	Counter()
20200709180116	Random	Counter((3, 10): 12, (3, 7): 10, (3, 3): 9, (10, 3): 5, (7, 7): 4, (7, 10): 3, (10, 7): 2, (7, 3): 2, (10, 3): 1, (10, 10): 1)
20200709180116	Cooperative Spite	Counter((10, 0): 4, (0, 0): 4, (10, 10): 2, (10, 10): 1)
20200709180116	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709180116	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)

20200709180116	Defector	Counter((0, 0): 3, (10, 0): 1)
20200709180116	Cooperative Light	Counter((0, 7): 39, (3, 7): 5, (7, 7): 4, (10, 7): 1)
20200709180116	Cooperative	Counter((0, 10): 38, (3, 10): 4, (10, 10): 3, (7, 10): 3, (10, 10): 1)
20200709180116	Defector Light	Counter((0, 3): 46, (3, 3): 2, (10, 3): 1)
20200709180935	Cooperative Spite	Counter((10, 10): 2, (7, 10): 1, (10, 0): 1, (7, 0): 1)
20200709180935	Tit for Tat	Counter((10, 10): 47, (7, 10): 1, (10, 7): 1)
20200709180935	Spiteful Tit for Tat	Counter((7, 7): 46, (10, 7): 2, (7, 10): 1)
20200709180935	Defector	Counter((0, 0): 2, (10, 0): 1)
20200709180935	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709180935	Defector Light	Counter()
20200709180935	Random	Counter((3, 7): 11, (3, 3): 10, (3, 10): 8, (7, 3): 5, (10, 3): 4, (10, 7): 3, (7, 7): 3, (10, 10): 2, (7, 10): 2, (10, 10): 1)
20200709180935	Cooperative Light	Counter()
20200709180935	Cooperative Spite	Counter()
20200709180935	Random	Counter((7, 7): 10, (7, 3): 8, (7, 10): 8, (10, 7): 5, (10, 10): 5, (3, 10): 4, (3, 7): 4, (3, 3): 3, (10, 7): 1, (10, 3): 1)
20200709180935	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709180935	Defector	Counter((0, 0): 4, (10, 0): 1, (3, 0): 1)

20200709180935	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709180935	Cooperative Light	Counter((0, 7): 26, (7, 7): 18, (3, 7): 4, (10, 7): 1)
20200709180935	Defector Light	Counter((3, 3): 45, (0, 3): 3, (10, 3): 1)
20200709180935	Cooperative	Counter()
20200709180935	Random	Counter((3, 10): 12, (3, 7): 10, (3, 3): 9, (10, 3): 5, (7, 7): 4, (7, 10): 3, (10, 7): 2, (7, 3): 2, (10, 3): 1, (10, 10): 1)
20200709180935	Cooperative Spite	Counter((10, 0): 4, (0, 0): 4, (10, 10): 2, (10, 10): 1)
20200709180935	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709180935	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709180935	Defector	Counter((0, 0): 3, (10, 0): 1)
20200709180935	Cooperative Light	Counter((0, 7): 39, (3, 7): 5, (7, 7): 4, (10, 7): 1)
20200709180935	Cooperative	Counter((0, 10): 38, (3, 10): 4, (10, 10): 3, (7, 10): 3, (10, 10): 1)
20200709180935	Defector Light	Counter((0, 3): 46, (3, 3): 2, (10, 3): 1)
20200709180935	Cooperative Light	Counter((0, 7): 45, (7, 7): 1, (10, 7): 1, (7, 7): 1, (3, 7): 1)
20200709180935	Tit for Tat	Counter((10, 10): 43, (10, 3): 2, (3, 3): 2, (3, 10): 1, (3, 10): 1)

20200709180935	Spiteful Tit for Tat	Counter((0, 0): 4, (10, 7): 2, (7, 7): 2, (7, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1)
20200709180935	Defector Light	Counter((0, 3): 46, (3, 3): 2, (7, 3): 1)
20200709180935	Cooperative Spite	Counter((10, 10): 2, (10, 0): 2, (0, 0): 2, (10, 10): 1)
20200709180935	Random	Counter((0, 10): 13, (0, 3): 12, (0, 7): 10, (10, 3): 3, (3, 3): 3, (10, 7): 2, (7, 7): 2, (3, 10): 2, (10, 10): 1, (7, 10): 1)
20200709180935	Defector	Counter((0, 0): 2, (10, 0): 1)
20200709180935	Cooperative	Counter((0, 10): 44, (10, 10): 4, (10, 10): 1)
20200709182027	Cooperative Spite	Counter((10, 10): 2, (7, 10): 1, (10, 0): 1, (7, 0): 1)
20200709182027	Tit for Tat	Counter((10, 10): 47, (7, 10): 1, (10, 7): 1)
20200709182027	Spiteful Tit for Tat	Counter((7, 7): 46, (10, 7): 2, (7, 10): 1)
20200709182027	Defector	Counter((0, 0): 2, (10, 0): 1)
20200709182027	Cooperative	Counter((10, 10): 48, (7, 10): 1)
20200709182027	Defector Light	Counter()
20200709182027	Random	Counter((3, 7): 11, (3, 3): 10, (3, 10): 8, (7, 3): 5, (10, 3): 4, (10, 7): 3, (7, 7): 3, (10, 10): 2, (7, 10): 2, (10, 10): 1)
20200709182027	Cooperative Light	Counter()
20200709182027	Cooperative Spite	Counter()

20200709182027	Random	Counter((7, 7): 10, (7, 3): 8, (7, 10): 8, (10, 7): 5, (10, 10): 5, (3, 10): 4, (3, 7): 4, (3, 3): 3, (10, 7): 1, (10, 3): 1)
20200709182027	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709182027	Defector	Counter((0, 0): 4, (10, 0): 1, (3, 0): 1)
20200709182027	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709182027	Cooperative Light	Counter((0, 7): 26, (7, 7): 18, (3, 7): 4, (10, 7): 1)
20200709182027	Defector Light	Counter((3, 3): 45, (0, 3): 3, (10, 3): 1)
20200709182027	Cooperative	Counter()
20200709182027	Random	Counter((3, 10): 12, (3, 7): 10, (3, 3): 9, (10, 3): 5, (7, 7): 4, (7, 10): 3, (10, 7): 2, (7, 3): 2, (10, 3): 1, (10, 10): 1)
20200709182027	Cooperative Spite	Counter((10, 0): 4, (0, 0): 4, (10, 10): 2, (10, 10): 1)
20200709182027	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709182027	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709182027	Defector	Counter((0, 0): 3, (10, 0): 1)
20200709182027	Cooperative Light	Counter((0, 7): 39, (3, 7): 5, (7, 7): 4, (10, 7): 1)
20200709182027	Cooperative	Counter((0, 10): 38, (3, 10): 4, (10, 10): 3, (7, 10): 3, (10, 10): 1)
20200709182027	Defector Light	Counter((0, 3): 46, (3, 3): 2, (10, 3): 1)

20200709182027	Cooperative Light	Counter((0, 7): 45, (7, 7): 1, (10, 7): 1, (7, 7): 1, (3, 7): 1)
20200709182027	Tit for Tat	Counter((10, 10): 43, (10, 3): 2, (3, 3): 2, (3, 10): 1, (3, 10): 1)
20200709182027	Spiteful Tit for Tat	Counter((0, 0): 4, (10, 7): 2, (7, 7): 2, (7, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1)
20200709182027	Defector Light	Counter((0, 3): 46, (3, 3): 2, (7, 3): 1)
20200709182027	Cooperative Spite	Counter((10, 10): 2, (10, 0): 2, (0, 0): 2, (10, 10): 1)
20200709182027	Random	Counter((0, 10): 13, (0, 3): 12, (0, 7): 10, (10, 3): 3, (3, 3): 3, (10, 7): 2, (7, 7): 2, (3, 10): 2, (10, 10): 1, (7, 10): 1)
20200709182027	Defector	Counter((0, 0): 2, (10, 0): 1)
20200709182027	Cooperative	Counter((0, 10): 44, (10, 10): 4, (10, 10): 1)
20200709182027	Random	Counter((0, 10): 18, (0, 3): 14, (0, 7): 13, (7, 3): 1, (3, 3): 1, (3, 7): 1, (3, 10): 1)
20200709182027	Tit for Tat	Counter((10, 10): 44, (0, 0): 2, (10, 10): 1, (0, 10): 1, (10, 0): 1)
20200709182027	Cooperative Spite	Counter((0, 0): 5, (10, 0): 3, (10, 10): 2, (10, 10): 1)
20200709182027	Defector	Counter((0, 0): 3, (10, 0): 1, (10, 0): 1)
20200709182027	Defector Light	Counter((0, 3): 45, (3, 3): 2, (10, 3): 1, (10, 3): 1)

20200709182027	Spiteful Tit for Tat	Counter({(10, 0): 4, (0, 0): 3, (10, 10): 2, (10, 10): 1, (0, 10): 1})
20200709182027	Cooperative	Counter({(0, 10): 47, (10, 10): 1, (10, 10): 1})
20200709182027	Cooperative Light	Counter({(0, 7): 45, (7, 7): 2, (10, 7): 1, (3, 7): 1})
20200709183131	Cooperative Spite	Counter({(10, 10): 2, (7, 10): 1, (10, 0): 1, (7, 0): 1})
20200709183131	Tit for Tat	Counter({(10, 10): 47, (7, 10): 1, (10, 7): 1})
20200709183131	Spiteful Tit for Tat	Counter({(7, 7): 46, (10, 7): 2, (7, 10): 1})
20200709183131	Defector	Counter({(0, 0): 2, (10, 0): 1})
20200709183131	Cooperative	Counter({(10, 10): 48, (7, 10): 1})
20200709183131	Defector Light	Counter()
20200709183131	Random	Counter({(3, 7): 11, (3, 3): 10, (3, 10): 8, (7, 3): 5, (10, 3): 4, (10, 7): 3, (7, 7): 3, (10, 10): 2, (7, 10): 2, (10, 10): 1})
20200709183131	Cooperative Light	Counter()
20200709183131	Cooperative Spite	Counter()
20200709183131	Random	Counter({(7, 7): 10, (7, 3): 8, (7, 10): 8, (10, 7): 5, (10, 10): 5, (3, 10): 4, (3, 7): 4, (3, 3): 3, (10, 7): 1, (10, 3): 1})
20200709183131	Tit for Tat	Counter({(10, 10): 48, (10, 10): 1})
20200709183131	Defector	Counter({(0, 0): 4, (10, 0): 1, (3, 0): 1})
20200709183131	Spiteful Tit for Tat	Counter({(10, 10): 48, (10, 10): 1})

20200709183131	Cooperative Light	Counter((0, 7): 26, (7, 7): 18, (3, 7): 4, (10, 7): 1)
20200709183131	Defector Light	Counter((3, 3): 45, (0, 3): 3, (10, 3): 1)
20200709183131	Cooperative	Counter()
20200709183131	Random	Counter((3, 10): 12, (3, 7): 10, (3, 3): 9, (10, 3): 5, (7, 7): 4, (7, 10): 3, (10, 7): 2, (7, 3): 2, (10, 3): 1, (10, 10): 1)
20200709183131	Cooperative Spite	Counter((10, 0): 4, (0, 0): 4, (10, 10): 2, (10, 10): 1)
20200709183131	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709183131	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200709183131	Defector	Counter((0, 0): 3, (10, 0): 1)
20200709183131	Cooperative Light	Counter((0, 7): 39, (3, 7): 5, (7, 7): 4, (10, 7): 1)
20200709183131	Cooperative	Counter((0, 10): 38, (3, 10): 4, (10, 10): 3, (7, 10): 3, (10, 10): 1)
20200709183131	Defector Light	Counter((0, 3): 46, (3, 3): 2, (10, 3): 1)
20200709183131	Cooperative Light	Counter((0, 7): 45, (7, 7): 1, (10, 7): 1, (7, 7): 1, (3, 7): 1)
20200709183131	Tit for Tat	Counter((10, 10): 43, (10, 3): 2, (3, 3): 2, (3, 10): 1, (3, 10): 1)
20200709183131	Spiteful Tit for Tat	Counter((0, 0): 4, (10, 7): 2, (7, 7): 2, (7, 0): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1)

20200709183131	Defector Light	Counter((0, 3): 46, (3, 3): 2, (7, 3): 1)
20200709183131	Cooperative Spite	Counter((10, 10): 2, (10, 0): 2, (0, 0): 2, (10, 10): 1)
20200709183131	Random	Counter((0, 10): 13, (0, 3): 12, (0, 7): 10, (10, 3): 3, (3, 3): 3, (10, 7): 2, (7, 7): 2, (3, 10): 2, (10, 10): 1, (7, 10): 1)
20200709183131	Defector	Counter((0, 0): 2, (10, 0): 1)
20200709183131	Cooperative	Counter((0, 10): 44, (10, 10): 4, (10, 10): 1)
20200709183131	Random	Counter((0, 10): 18, (0, 3): 14, (0, 7): 13, (7, 3): 1, (3, 3): 1, (3, 7): 1, (3, 10): 1)
20200709183131	Tit for Tat	Counter((10, 10): 44, (0, 0): 2, (10, 10): 1, (0, 10): 1, (10, 0): 1)
20200709183131	Cooperative Spite	Counter((0, 0): 5, (10, 0): 3, (10, 10): 2, (10, 10): 1)
20200709183131	Defector	Counter((0, 0): 3, (10, 0): 1, (10, 0): 1)
20200709183131	Defector Light	Counter((0, 3): 45, (3, 3): 2, (10, 3): 1, (10, 3): 1)
20200709183131	Spiteful Tit for Tat	Counter((10, 0): 4, (0, 0): 3, (10, 10): 2, (10, 10): 1, (0, 10): 1)
20200709183131	Cooperative	Counter((0, 10): 47, (10, 10): 1, (10, 10): 1)
20200709183131	Cooperative Light	Counter((0, 7): 45, (7, 7): 2, (10, 7): 1, (3, 7): 1)

20200709183131	Random	Counter((10, 7): 8, (3, 3): 8, (7, 10): 7, (7, 3): 6, (3, 10): 6, (3, 7): 5, (10, 10): 4, (10, 3): 4, (3, 3): 1)
20200709183131	Spiteful Tit for Tat	Counter((7, 7): 9, (10, 7): 3, (0, 0): 3, (7, 0): 2, (7, 10): 1, (3, 7): 1, (3, 3): 1, (0, 3): 1)
20200709183131	Defector	Counter((3, 0): 2, (0, 0): 1)
20200709183131	Tit for Tat	Counter((10, 10): 46, (7, 10): 1, (7, 7): 1, (10, 7): 1)
20200709183131	Cooperative Spite	Counter((10, 10): 2, (0, 0): 2, (10, 0): 2, (3, 10): 1, (3, 0): 1)
20200709183131	Defector Light	Counter((0, 3): 46, (7, 3): 2, (3, 3): 1)
20200709183131	Cooperative	Counter((0, 10): 46, (10, 10): 2, (7, 10): 1)
20200709183131	Cooperative Light	Counter((0, 7): 43, (10, 7): 2, (7, 7): 2, (7, 7): 1, (3, 7): 1)
20200710111927	Cooperative Spite	Counter((7, 10): 2, (3, 0): 2, (10, 0): 2, (7, 10): 1, (0, 0): 1)
20200710111927	Spiteful Tit for Tat	Counter((7, 7): 3, (3, 3): 3, (10, 3): 3, (7, 10): 1, (3, 7): 1)
20200710111927	Defector Light	Counter((7, 3): 1, (7, 3): 1)
20200710111927	Defector	Counter((7, 0): 2, (7, 0): 1)
20200710111927	Tit for Tat	Counter((10, 10): 15, (7, 7): 3, (7, 10): 1, (10, 7): 1)
20200710111927	Cooperative Light	Counter((0, 7): 25, (7, 7): 2, (3, 7): 2, (7, 7): 1)

20200710111927	Random	Counter((3, 10): 5, (0, 3): 4, (3, 3): 2, (0, 10): 2, (7, 3): 1, (3, 7): 1)
20200710114442	Cooperative	Counter()
20200710115018	Tit for Tat	Counter((10, 10): 36, (7, 7): 10, (10, 10): 1, (7, 10): 1, (10, 7): 1)
20200710115018	Cooperative Spite	Counter((0, 0): 41, (10, 0): 5, (10, 10): 2, (10, 10): 1)
20200710115018	Cooperative Light	Counter((7, 7): 47, (7, 7): 1, (3, 7): 1)
20200710125153	Cooperative Spite	Counter((10, 10): 2, (0, 0): 2, (7, 10): 1, (10, 0): 1, (7, 0): 1)
20200710125153	Defector Light	Counter((3, 3): 47, (10, 3): 1, (7, 3): 1)
20200710125153	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200710125153	Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200710125153	Defector	Counter((0, 0): 8, (10, 0): 1, (7, 0): 1)
20200710125153	Random	Counter((7, 10): 9, (7, 7): 8, (3, 7): 7, (10, 7): 6, (10, 10): 6, (10, 3): 6, (7, 3): 4, (3, 10): 2, (10, 10): 1)
20200710125153	Cooperative Light	Counter((7, 7): 48, (10, 7): 1)
20200710130233	Random	Counter((7, 10): 3, (7, 7): 2, (10, 3): 2, (3, 7): 2, (10, 10): 2, (3, 3): 2, (7, 3): 2, (10, 7): 1)
20200710130915	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710131117	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710131117	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)

20200710131748	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710131748	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)
20200710131748	Random	Counter()
20200710131748	Defector	Counter((0, 0): 21, (3, 0): 15, (7, 0): 10, (10, 0): 2, (3, 0): 1)
20200710131958	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710131958	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)
20200710131958	Random	Counter()
20200710131958	Defector	Counter((0, 0): 21, (3, 0): 15, (7, 0): 10, (10, 0): 2, (3, 0): 1)
20200710131958	Tit for Tat	Counter((10, 10): 31, (7, 7): 6, (3, 3): 4, (0, 0): 3, (7, 10): 1, (0, 7): 1, (3, 0): 1, (7, 3): 1, (10, 7): 1)
20200710132202	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710132202	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)
20200710132202	Random	Counter()
20200710132202	Defector	Counter((0, 0): 21, (3, 0): 15, (7, 0): 10, (10, 0): 2, (3, 0): 1)
20200710132202	Tit for Tat	Counter((10, 10): 31, (7, 7): 6, (3, 3): 4, (0, 0): 3, (7, 10): 1, (0, 7): 1, (3, 0): 1, (7, 3): 1, (10, 7): 1)
20200710132202	Cooperative Light	Counter((7, 7): 41, (3, 7): 4, (0, 7): 3, (0, 7): 1)
20200710132317	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)

20200710132317	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)
20200710132317	Random	Counter()
20200710132317	Defector	Counter((0, 0): 21, (3, 0): 15, (7, 0): 10, (10, 0): 2, (3, 0): 1)
20200710132317	Tit for Tat	Counter((10, 10): 31, (7, 7): 6, (3, 3): 4, (0, 0): 3, (7, 10): 1, (0, 7): 1, (3, 0): 1, (7, 3): 1, (10, 7): 1)
20200710132317	Cooperative Light	Counter((7, 7): 41, (3, 7): 4, (0, 7): 3, (0, 7): 1)
20200710132317	Cooperative Light	Counter((7, 7): 14, (3, 7): 3, (10, 7): 2, (10, 7): 1)
20200710132410	Cooperative Spite	Counter((10, 10): 1)
20200710132410	Defector	Counter((3, 0): 1)
20200710132410	Tit for Tat	Counter((0, 10): 1)
20200710132410	Random	Counter((10, 7): 1)
20200710132410	Cooperative Light	Counter((3, 7): 1)
20200710132427	Defector Light	Counter((0, 3): 46, (7, 3): 1, (7, 3): 1, (10, 3): 1)
20200710132427	Random	Counter((0, 10): 16, (0, 7): 10, (0, 3): 9, (7, 7): 4, (3, 7): 2, (7, 3): 2, (7, 10): 2, (3, 3): 1, (3, 10): 1, (10, 10): 1, (10, 3): 1)
20200710132427	Spiteful Tit for Tat	Counter((7, 0): 3, (7, 7): 2, (0, 0): 2, (10, 0): 2, (7, 10): 1, (0, 7): 1, (3, 0): 1)

20200710132427	Cooperative Light	Counter((0, 7): 42, (7, 7): 3, (3, 7): 3, (10, 7): 1)
20200710132427	Tit for Tat	Counter((3, 3): 4, (7, 7): 3, (7, 3): 2, (10, 10): 2, (3, 10): 1, (3, 7): 1, (10, 7): 1)
20200710132427	Defector	Counter((10, 0): 1, (7, 0): 1, (3, 0): 1, (0, 0): 1)
20200710132427	Cooperative	Counter((0, 10): 48, (0, 10): 1)
20200710132427	Cooperative Spite	Counter((7, 0): 5, (0, 0): 2, (7, 10): 1, (7, 10): 1, (0, 10): 1, (10, 0): 1)
20200710132519	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710132519	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)
20200710132519	Random	Counter()
20200710132519	Defector	Counter((0, 0): 21, (3, 0): 15, (7, 0): 10, (10, 0): 2, (3, 0): 1)
20200710132519	Tit for Tat	Counter((10, 10): 31, (7, 7): 6, (3, 3): 4, (0, 0): 3, (7, 10): 1, (0, 7): 1, (3, 0): 1, (7, 3): 1, (10, 7): 1)
20200710132519	Cooperative Light	Counter((7, 7): 41, (3, 7): 4, (0, 7): 3, (0, 7): 1)
20200710132519	Cooperative Light	Counter((7, 7): 14, (3, 7): 3, (10, 7): 2, (10, 7): 1)
20200710132519	Defector Light	Counter((3, 3): 45, (0, 3): 3, (0, 3): 1)
20200710132714	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710132714	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)
20200710132714	Random	Counter()

20200710132714	Defector	Counter((0, 0): 21, (3, 0): 15, (7, 0): 10, (10, 0): 2, (3, 0): 1)
20200710132714	Tit for Tat	Counter((10, 10): 31, (7, 7): 6, (3, 3): 4, (0, 0): 3, (7, 10): 1, (0, 7): 1, (3, 0): 1, (7, 3): 1, (10, 7): 1)
20200710132714	Cooperative Light	Counter((7, 7): 41, (3, 7): 4, (0, 7): 3, (0, 7): 1)
20200710132714	Cooperative Light	Counter((7, 7): 14, (3, 7): 3, (10, 7): 2, (10, 7): 1)
20200710132714	Defector Light	Counter((3, 3): 45, (0, 3): 3, (0, 3): 1)
20200710132714	Cooperative Light	Counter((7, 7): 43, (3, 7): 5, (7, 7): 1)
20200710132725	Cooperative	Counter((7, 10): 12, (3, 10): 8, (10, 10): 4, (0, 10): 4, (10, 10): 1)
20200710132846	Cooperative	Counter((7, 10): 12, (3, 10): 8, (10, 10): 4, (0, 10): 4, (10, 10): 1)
20200710132846	Defector	Counter((0, 0): 4, (3, 0): 3, (10, 0): 1)
20200710132850	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710132850	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)
20200710132850	Random	Counter()
20200710132850	Defector	Counter((0, 0): 21, (3, 0): 15, (7, 0): 10, (10, 0): 2, (3, 0): 1)
20200710132850	Tit for Tat	Counter((10, 10): 31, (7, 7): 6, (3, 3): 4, (0, 0): 3, (7, 10): 1, (0, 7): 1, (3, 0): 1, (7, 3): 1, (10, 7): 1)

20200710132850	Cooperative Light	Counter((7, 7): 41, (3, 7): 4, (0, 7): 3, (0, 7): 1)
20200710132850	Cooperative Light	Counter((7, 7): 14, (3, 7): 3, (10, 7): 2, (10, 7): 1)
20200710132850	Defector Light	Counter((3, 3): 45, (0, 3): 3, (0, 3): 1)
20200710132850	Cooperative Light	Counter((7, 7): 43, (3, 7): 5, (7, 7): 1)
20200710132850	Defector	Counter((0, 0): 10, (3, 0): 5, (10, 0): 3, (7, 0): 2, (3, 0): 1)
20200710132955	Random	Counter((7, 3): 9, (7, 7): 7, (7, 10): 5, (3, 7): 3, (7, 10): 1, (3, 3): 1, (10, 7): 1)
20200710132955	Defector	Counter((0, 0): 12, (3, 0): 3, (7, 0): 1, (7, 0): 1)
20200710132955	Cooperative Spite	Counter((3, 0): 4, (0, 0): 4, (7, 10): 2, (10, 0): 2, (7, 10): 1, (7, 0): 1)
20200710132955	Tit for Tat	Counter((10, 10): 8, (7, 7): 6, (7, 10): 1, (10, 7): 1)
20200710132955	Cooperative Light	Counter((7, 7): 10, (10, 7): 2, (7, 7): 1)
20200710132955	Cooperative	Counter((10, 10): 7, (7, 10): 1, (7, 10): 1)
20200710132955	Defector Light	Counter((3, 3): 8, (7, 3): 2, (7, 3): 1)
20200710132955	Spiteful Tit for Tat	Counter((7, 7): 8, (10, 7): 2, (7, 10): 1)
20200710133041	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710133041	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)
20200710133041	Random	Counter()
20200710133041	Defector	Counter((0, 0): 21, (3, 0): 15, (7, 0): 10, (10, 0): 2, (3, 0): 1)

20200710133041	Tit for Tat	Counter((10, 10): 31, (7, 7): 6, (3, 3): 4, (0, 0): 3, (7, 10): 1, (0, 7): 1, (3, 0): 1, (7, 3): 1, (10, 7): 1)
20200710133041	Cooperative Light	Counter((7, 7): 41, (3, 7): 4, (0, 7): 3, (0, 7): 1)
20200710133041	Cooperative Light	Counter((7, 7): 14, (3, 7): 3, (10, 7): 2, (10, 7): 1)
20200710133041	Defector Light	Counter((3, 3): 45, (0, 3): 3, (0, 3): 1)
20200710133041	Cooperative Light	Counter((7, 7): 43, (3, 7): 5, (7, 7): 1)
20200710133041	Defector	Counter((0, 0): 10, (3, 0): 5, (10, 0): 3, (7, 0): 2, (3, 0): 1)
20200710133041	Cooperative	Counter((10, 10): 40, (7, 10): 8, (10, 10): 1)
20200710133332	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710133332	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)
20200710133332	Random	Counter()
20200710133332	Defector	Counter((0, 0): 21, (3, 0): 15, (7, 0): 10, (10, 0): 2, (3, 0): 1)
20200710133332	Tit for Tat	Counter((10, 10): 31, (7, 7): 6, (3, 3): 4, (0, 0): 3, (7, 10): 1, (0, 7): 1, (3, 0): 1, (7, 3): 1, (10, 7): 1)
20200710133332	Cooperative Light	Counter((7, 7): 41, (3, 7): 4, (0, 7): 3, (0, 7): 1)
20200710133332	Cooperative Light	Counter((7, 7): 14, (3, 7): 3, (10, 7): 2, (10, 7): 1)
20200710133332	Defector Light	Counter((3, 3): 45, (0, 3): 3, (0, 3): 1)

20200710133332	Cooperative Light	Counter((7, 7): 43, (3, 7): 5, (7, 7): 1)
20200710133332	Defector	Counter((0, 0): 10, (3, 0): 5, (10, 0): 3, (7, 0): 2, (3, 0): 1)
20200710133332	Cooperative	Counter((10, 10): 40, (7, 10): 8, (10, 10): 1)
20200710133332	Random	Counter((7, 7): 7, (3, 3): 6, (0, 3): 5, (3, 10): 5, (3, 7): 5, (7, 3): 4, (7, 10): 4, (10, 10): 4, (10, 7): 3, (10, 3): 3, (0, 7): 2, (0, 3): 1)
20200710133621	Cooperative	Counter((7, 10): 42, (10, 10): 6, (7, 10): 1)
20200710133621	Cooperative Light	Counter((7, 7): 43, (0, 7): 5, (0, 7): 1)
20200710133621	Random	Counter()
20200710133621	Defector	Counter((0, 0): 21, (3, 0): 15, (7, 0): 10, (10, 0): 2, (3, 0): 1)
20200710133621	Tit for Tat	Counter((10, 10): 31, (7, 7): 6, (3, 3): 4, (0, 0): 3, (7, 10): 1, (0, 7): 1, (3, 0): 1, (7, 3): 1, (10, 7): 1)
20200710133621	Cooperative Light	Counter((7, 7): 41, (3, 7): 4, (0, 7): 3, (0, 7): 1)
20200710133621	Cooperative Light	Counter((7, 7): 14, (3, 7): 3, (10, 7): 2, (10, 7): 1)
20200710133621	Defector Light	Counter((3, 3): 45, (0, 3): 3, (0, 3): 1)
20200710133621	Cooperative Light	Counter((7, 7): 43, (3, 7): 5, (7, 7): 1)
20200710133621	Defector	Counter((0, 0): 10, (3, 0): 5, (10, 0): 3, (7, 0): 2, (3, 0): 1)
20200710133621	Cooperative	Counter((10, 10): 40, (7, 10): 8, (10, 10): 1)

20200710133621	Random	Counter((7, 7): 7, (3, 3): 6, (0, 3): 5, (3, 10): 5, (3, 7): 5, (7, 3): 4, (7, 10): 4, (10, 10): 4, (10, 7): 3, (10, 3): 3, (0, 7): 2, (0, 3): 1)
20200710133621	Defector	Counter((0, 0): 13, (3, 0): 6, (10, 0): 3, (0, 0): 1, (7, 0): 1)
20200710134042	Defector Light	Counter()
20200710134042	Defector	Counter((0, 0): 26, (3, 0): 13, (7, 0): 5, (10, 0): 4, (10, 0): 1)
20200710140332	Cooperative Spite	Counter((3, 0): 3, (10, 10): 2, (7, 10): 1, (10, 0): 1, (0, 0): 1)
20200710140332	Cooperative	Counter((10, 10): 45, (7, 10): 3, (7, 10): 1)
20200710140332	Defector	Counter((3, 0): 2, (0, 0): 2, (7, 0): 1)
20200710140332	Tit for Tat	Counter((10, 10): 28, (10, 7): 2, (7, 10): 1, (7, 10): 1)
20200710140332	Random	Counter((10, 10): 7, (10, 7): 6, (7, 7): 3, (3, 7): 3, (7, 10): 3, (10, 3): 2, (3, 10): 2, (7, 10): 1, (7, 3): 1, (3, 3): 1)
20200710140332	Spiteful Tit for Tat	Counter((7, 7): 5, (10, 7): 3, (7, 3): 3, (3, 3): 2, (7, 10): 1, (3, 7): 1, (0, 3): 1, (3, 0): 1)
20200710140818	Spiteful Tit for Tat	Counter()
20200710140818	Cooperative	Counter()
20200710140818	Random	Counter()

20200710140818	Cooperative Spite	Counter({(3, 0): 39, (10, 0): 3, (0, 0): 3, (3, 10): 2, (7, 10): 1, (7, 0): 1})
20200710142144	Spiteful Tit for Tat	Counter({(7, 7): 8, (10, 7): 5, (7, 0): 2, (0, 0): 2, (7, 10): 1, (0, 7): 1})
20200710142144	Defector Light	Counter({(0, 3): 44, (7, 3): 3, (10, 3): 1, (10, 3): 1})
20200710142144	Tit for Tat	Counter({(10, 10): 46, (7, 10): 1, (10, 7): 1, (0, 10): 1})
20200710142144	Cooperative	Counter({(0, 10): 27, (10, 10): 16, (7, 10): 4, (7, 10): 1, (3, 10): 1})
20200710142144	Cooperative Light	Counter({(0, 7): 45, (10, 7): 3, (7, 7): 1})
20200710142144	Random	Counter({(0, 10): 17, (0, 7): 17, (0, 3): 11, (7, 3): 1, (10, 10): 1, (10, 7): 1, (10, 3): 1})
20200710142144	Defector	Counter({(0, 0): 2, (7, 0): 1, (10, 0): 1, (7, 0): 1})
20200710142144	Cooperative Spite	Counter({(0, 0): 3, (10, 10): 2, (7, 10): 1, (7, 0): 1, (10, 0): 1})
20200710160610	Cooperative	Counter({(3, 10): 1})
20200710160610	Random	Counter({(10, 7): 1})
20200710160610	Defector Light	Counter({(3, 3): 1})
20200710160610	Cooperative Light	Counter({(7, 7): 1})
20200710160610	Tit for Tat	Counter({(0, 10): 1})
20200710160610	Defector	Counter({(10, 0): 1})
20200710160610	Spiteful Tit for Tat	Counter({(7, 10): 1})

20200710160610	Cooperative Spite	Counter((10, 10): 1)
20200710160929	Defector	Counter((7, 0): 1, (3, 0): 1)
20200710160929	Cooperative Spite	Counter((10, 10): 2, (3, 0): 2, (7, 10): 1, (10, 0): 1)
20200710160929	Cooperative	Counter((10, 10): 16, (7, 10): 1)
20200710160929	Defector Light	Counter((0, 3): 4, (7, 3): 1, (7, 3): 1, (3, 3): 1)
20200710160929	Cooperative Light	Counter((7, 7): 4, (10, 7): 3, (0, 7): 2, (7, 7): 1)
20200710160929	Spiteful Tit for Tat	Counter((7, 7): 4, (7, 10): 1, (10, 7): 1, (3, 7): 1, (3, 3): 1, (0, 3): 1, (0, 0): 1)
20200710160929	Random	Counter((7, 7): 3, (0, 7): 2, (3, 3): 2, (0, 3): 2, (7, 3): 2, (7, 3): 1, (3, 10): 1, (10, 7): 1, (0, 10): 1)
20200710160929	Tit for Tat	Counter((7, 10): 1, (10, 7): 1, (3, 10): 1, (7, 3): 1, (0, 7): 1)
20200710163800	Tit for Tat	Counter()
20200710163800	Cooperative	Counter((10, 10): 6, (0, 10): 3, (7, 10): 1, (7, 10): 1)
20200710163800	Random	Counter((3, 3): 2, (3, 10): 2, (7, 3): 1, (7, 3): 1, (3, 7): 1, (7, 10): 1, (10, 3): 1)
20200710163800	Spiteful Tit for Tat	Counter((7, 3): 3, (3, 3): 3, (7, 10): 1, (7, 7): 1, (3, 7): 1)
20200710163800	Defector Light	Counter((3, 3): 7, (7, 3): 2, (7, 3): 1)

20200710163800	Cooperative Spite	Counter((3, 0): 3, (10, 10): 2, (7, 0): 2, (10, 10): 1, (10, 0): 1)
20200710163800	Defector	Counter((3, 0): 5, (7, 0): 1, (7, 0): 1)
20200710163800	Cooperative Light	Counter((7, 7): 4, (0, 7): 4, (3, 7): 3, (10, 7): 2, (7, 7): 1)
20200710190540	Cooperative Light	Counter((0, 7): 40, (7, 7): 7, (7, 7): 1, (3, 7): 1)
20200711004851	Spiteful Tit for Tat	Counter((0, 0): 5, (10, 0): 3, (7, 10): 1, (10, 7): 1, (0, 7): 1, (3, 0): 1)
20200711004851	Defector Light	Counter((10, 3): 10, (3, 3): 10, (7, 3): 5, (10, 3): 1, (0, 3): 1)
20200711160258	Cooperative Spite	Counter((0, 0): 10, (10, 0): 3, (10, 10): 2, (10, 10): 1)
20200711160258	Random	Counter((10, 3): 7, (10, 10): 5, (10, 7): 5, (10, 7): 1)
20200711160258	Cooperative	Counter((10, 10): 48, (10, 10): 1)
20200711160258	Spiteful Tit for Tat	Counter((10, 10): 48, (10, 10): 1)
20200712140551	Defector	Counter((0, 0): 21, (3, 0): 11, (7, 0): 10, (10, 0): 6, (7, 0): 1)
20200712140551	Tit for Tat	Counter((0, 0): 16, (3, 3): 10, (0, 3): 7, (3, 0): 5, (3, 7): 4, (7, 0): 2, (7, 3): 2, (10, 10): 1, (0, 10): 1, (7, 7): 1)
20200712155841	Cooperative	Counter((10, 10): 9, (10, 10): 1)

20200712155841	Random	Counter((10, 7): 2, (7, 10): 2, (10, 10): 2, (3, 7): 2, (10, 10): 1, (10, 3): 1)
20200713100649	Spiteful Tit for Tat	Counter()
20200713100649	Defector	Counter((3, 0): 2, (7, 0): 1)
20200713100649	Cooperative Light	Counter()
20200713100649	Cooperative	Counter((0, 10): 4, (3, 10): 2, (3, 10): 1, (7, 10): 1)
20200713100649	Random	Counter((7, 7): 3, (3, 3): 2, (0, 7): 2, (0, 10): 2, (10, 7): 1, (7, 3): 1, (10, 3): 1, (10, 10): 1)
20200713100649	Defector Light	Counter((0, 3): 3, (3, 3): 2, (7, 3): 1)
20200713100649	Cooperative Spite	Counter((3, 0): 2, (10, 10): 1, (7, 10): 1, (3, 10): 1, (0, 0): 1)
20200713113437	Tit for Tat	Counter()
20200713113437	Cooperative Light	Counter((7, 7): 13, (0, 7): 4, (10, 7): 3, (3, 7): 1)
20200713113437	Cooperative Spite	Counter((0, 0): 4, (10, 10): 2, (7, 0): 2, (7, 10): 1, (10, 0): 1)
20200713115330	Defector Light	Counter((7, 3): 11, (7, 3): 1)
20200713115330	Tit for Tat	Counter((7, 10): 1)
20200713115330	Cooperative Light	Counter((7, 7): 48, (7, 7): 1)
20200713145541	Random	Counter()
20200713145541	Cooperative Light	Counter()

20200713145541	Spiteful Tit for Tat	Counter((10, 10): 1, (10, 10): 1, (7, 10): 1, (10, 7): 1)
20200714150910	Cooperative Spite	Counter((3, 0): 15, (0, 0): 9, (7, 10): 1, (3, 10): 1, (0, 10): 1, (7, 0): 1, (10, 0): 1)
20200714205920	Random	Counter()
20200714210818	Cooperative Light	Counter((10, 7): 1, (7, 7): 1, (3, 7): 1)
20200714210818	Defector Light	Counter((3, 3): 3, (10, 3): 1, (0, 3): 1)
20200714210818	Spiteful Tit for Tat	Counter((7, 7): 13, (7, 10): 1, (10, 7): 1)
20200714210818	Random	Counter((7, 7): 4, (3, 7): 3, (7, 3): 1, (3, 10): 1, (10, 3): 1, (7, 10): 1, (7, 3): 1)
20200714210818	Tit for Tat	Counter()

Table G.1: Mod-SYMLOG Chapter 5 Exp 1 Data In Counter Form

Appendix H

Mod-Snowdrift Experiment 3 Instructions And Consent

Information

This experiment is part of a Computer Science PhD project on modelling human behaviour in classrooms.

In this experiment you will play a "game" called Snowdrift.

This type of game is not a one you may be used to. The term game here is taken from a subject called Game Theory, where researchers try to model human behaviour by restricting actions that players can make in a situation. These restrictions are called rules.

Snowdrift is a game which tries to model cooperative behaviour between 2 or more players.

In this experiment you will be playing with multiple AI opponents, chosen at random, for a maximum of 50 turns per AI opponent.

Each interaction with a single AI opponent is called a match.

Each match is made up of multiple turns.

A turn is when you made a single choice.

Each turn you receive £10. You are then given a series of 4 options of how you would like to split the money you are given.

In each match you will be asked to split some money between yourself and a central pot of money

– Pay £10 to a public pot, keep £0

– Pay £7to a public pot, keep £3

– Pay £3to a public pot, keep £7

– Pay £0 to a public pot, keep £10

The AI player will get the same choices as you

Any money added to the pot will get a 10% bonus. Half of this total will be returned to you, and half to the AI.

You can choose to play a new AI whenever you wish

At the end of the 50 matches you will be given a new AI opponent.

The experiment will end either when you choose to end it, or when all AI opponents have been played.

No personal data will be collected in this experiment.

If you wish for any further information please contact elongf@essex.ac.uk

Consent

By taking part in this experiment, I am consenting that the record of turns between myself and AI opponents will be recorded and may be published either as part of a PhD thesis or a paper for an academic journal/conference.

Appendix I

Mod-Snowdrift Experiment 3 Results

I.1 Totals Only

"Q1 C" means "Question 1 Correct Answer"

"Q1 A" means "Question 1 Answer Given"

Q1 C	Q1 A	Q2 C	Q2 A	Q3 C	Q3 A	Q4 C	Q4 A	Q5 C	Q5 A
GC	GC	LC	MC	LC	VC	LC	HC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	LC	LC	VC	LC	HC	LC	GC	VL	GC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC

GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	LC	LC	LC	VL	LC
GC	GC	LC	MC	LC	GC	LC	HC	VL	GC
GC	HC	LC	MC	LC	LC	LC	VC	VL	NC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	HC	LC	GC	LC	GC	LC	MC	VL	LC
GC	HC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	0	LC	0	LC	0	LC	0	VL	0
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	HC	LC	HC	LC	GC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC

GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	HC	LC	GC	LC	MC	LC	VC	VL	LC
GC	GC	LC	GC	LC	MC	LC	MC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	HC	LC	GC	LC	MC	LC	VC	VL	LC
GC	0	LC	0	LC	0	LC	0	VL	0
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	GC	LC	GC	LC	LC	VL	VC

GC	HC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	MC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC

GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	HC	LC	MC	LC	LC	LC	LC	VL	VC
GC	HC	LC	MC	LC	MC	LC	MC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	HC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	0
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	HC	LC	GC	LC	MC	LC	LC	VL	NC
GC	HC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	HC	LC	GC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	LC	LC	VC	VL	NC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC

GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	HC	LC	MC	LC	LC	LC	VC	VL	NC
GC	MC	LC	LC	LC	LC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	MC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	HC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	HC	LC	GC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	0	LC	0	LC	0	LC	0	VL	0
GC	LC	LC	HC	LC	0	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	LC	VL	LC
GC	GC	LC	MC	LC	MC	LC	VC	VL	VC
GC	GC	LC	MC	LC	LC	LC	VC	VL	NC
GC	GC	LC	LC	LC	VC	LC	VC	VL	NC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC
GC	GC	LC	MC	LC	MC	LC	LC	VL	VC

GC	GC	LC	MC	LC	MC	LC	LC	VL	LC

Table I.1: Mod-SYMLOG Chapter 5 Experiment 3 Totals Only

I.2 Totals and Diagrams

"Q1 C" means "Question 1 Correct Answer"

"Q1 A" means "Question 1 Answer Given"

Q1 C	Q1 A	Q2 C	Q2 A	Q3 C	Q3 A	Q4 C	Q4 A	Q5 C	Q5 A
GC	GC	MC	GC	LC	LC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	GC	LC	MC	LC	LC	VL	VC
GC	0	MC	0	LC	0	LC	0	VL	0
GC	GC	MC	MC	LC	LC	LC	LC	VL	LC
GC	0	MC	0	LC	0	LC	0	VL	0
GC	MC	MC	GC	LC	MC	LC	VC	VL	VC
GC	GC	MC	MC	LC	GC	LC	HC	VL	LC
GC	HC	MC	HC	LC	MC	LC	MC	VL	VC
GC	HC	MC	HC	LC	MC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	GC	LC	LC	LC	LC	VL	VC

GC	HC	MC	HC	LC	GC	LC	LC	VL	VC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	MC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	VC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	LC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	HC	MC	MC	LC	LC	LC	VC	VL	VC
GC	MC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	MC	MC	MC	LC	LC	LC	VC	VL	VC
GC	GC	MC	MC	LC	LC	LC	VC	VL	NC
GC	HC	MC	HC	LC	MC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	GC	LC	MC	LC	LC	VL	VC
GC	GC	MC	GC	LC	LC	LC	LC	VL	VC
GC	GC	MC	GC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	HC	MC	HC	LC	LC	LC	MC	VL	LC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	GC	MC	HC	LC	MC	LC	LC	VL	LC

GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	GC	MC	GC	LC	MC	LC	MC	VL	MC
GC	0	MC	0	LC	0	LC	0	VL	0
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	VC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	HC	MC	HC	LC	GC	LC	MC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	LC	LC	VC	LC	MC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	GC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	HC	MC	HC	LC	MC	LC	LC	VL	LC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	GC	MC	LC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	GC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	GC	MC	GC	LC	LC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC

GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	GC	MC	0	LC	GC	LC	MC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	LC
GC	HC	MC	GC	LC	LC	LC	VC	VL	VC
GC	GC	MC	MC	LC	LC	LC	VC	VL	VC
GC	HC	MC	GC	LC	LC	LC	LC	VL	LC
GC	GC	MC	HC	LC	MC	LC	LC	VL	LC
GC	HC	MC	HC	LC	MC	LC	LC	VL	VC
GC	HC	MC	GC	LC	MC	LC	VC	VL	MC
GC	GC	MC	GC	LC	LC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	VC	VL	VC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	HC	MC	HC	LC	LC	LC	VC	VL	LC
GC	MC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	HC	MC	GC	LC	GC	LC	MC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	GC	VL	MC
GC	GC	MC	MC	LC	LC	LC	VC	VL	VC

GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	MC	LC	MC	LC	MC	VL	LC
GC	GC	MC	LC	LC	LC	LC	LC	VL	NC
GC	MC	MC	MC	LC	LC	LC	LC	VL	LC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	MC	MC	HC	LC	MC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	VC	VL	NC
GC	GC	MC	MC	LC	MC	LC	LC	VL	VC
GC	GC	MC	MC	LC	LC	LC	VC	VL	VC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	HC	MC	HC	LC	MC	LC	LC	VL	LC
GC	HC	MC	LC	LC	GC	LC	GC	VL	LC
GC	GC	MC	GC	LC	MC	LC	LC	VL	VC
GC	GC	MC	GC	LC	MC	LC	LC	VL	LC
GC	GC	MC	HC	LC	MC	LC	LC	VL	LC
GC	GC	MC	MC	LC	LC	LC	LC	VL	VC

Table I.2: Mod-SYMLOG Chapter 5 Experiment 3 Totals And Diagrams

I.3 Diagrams Only

"Q1 C" means "Question 1 Correct Answer"

"Q1 A" means "Question 1 Answer Given"

Q1 C	Q1 A	Q2 C	Q2 A	Q3 C	Q3 A	Q4 C	Q4 A	Q5 C	Q5 A
MC	MC	HC	LC	LC	LC	LC	LC	VC	VC
MC	MC	HC	LC	LC	LC	LC	LC	VC	LC
MC	MC	HC	GC	LC	MC	LC	LC	VC	VC
MC	HC	HC	GC	LC	MC	LC	LC	VC	VC
MC	0	HC	0	LC	0	LC	0	VC	0
MC	GC	HC	HC	LC	LC	LC	MC	VC	VC
MC	GC	HC	HC	LC	LC	LC	MC	VC	VC
MC	HC	HC	GC	LC	LC	LC	HC	VC	GC
MC	GC	HC	HC	LC	MC	LC	LC	VC	VC
MC	GC	HC	HC	LC	GC	LC	GC	VC	LC
MC	MC	HC	HC	LC	MC	LC	LC	VC	VC
MC	GC	HC	HC	LC	MC	LC	MC	VC	VC
MC	HC	HC	GC	LC	MC	LC	LC	VC	VC
MC	GC	HC	HC	LC	LC	LC	LC	VC	VC
MC	GC	HC	HC	LC	MC	LC	LC	VC	NC
MC	GC	HC	HC	LC	MC	LC	LC	VC	NC
MC	MC	HC	HC	LC	LC	LC	LC	VC	VC
MC	MC	HC	HC	LC	MC	LC	MC	VC	VC
MC	GC	HC	MC	LC	MC	LC	HC	VC	LC

MC	MC	HC	GC	LC	MC	LC	LC	VC	VC
MC	HC	HC	HC	LC	GC	LC	MC	VC	VC
MC	HC	HC	GC	LC	MC	LC	MC	VC	VC
MC	GC	HC	MC	LC	MC	LC	LC	VC	VC
MC	GC	HC	HC	LC	LC	LC	MC	VC	VC
MC	MC	HC	HC	LC	MC	LC	MC	VC	LC
MC	HC	HC	HC	LC	GC	LC	MC	VC	LC
MC	MC	HC	GC	LC	LC	LC	LC	VC	VC
MC	GC	HC	GC	LC	MC	LC	MC	VC	VC
MC	MC	HC	MC	LC	MC	LC	LC	VC	VC
MC	GC	HC	GC	LC	MC	LC	MC	VC	LC
MC	MC	HC	HC	LC	LC	LC	LC	VC	VC
MC	GC	HC	GC	LC	LC	LC	LC	VC	VC
MC	HC	HC	HC	LC	MC	LC	MC	VC	LC
MC	GC	HC	GC	LC	MC	LC	LC	VC	VC
MC	GC	HC	HC	LC	GC	LC	MC	VC	LC
MC	GC	HC	HC	LC	MC	LC	LC	VC	VC
MC	HC	HC	HC	LC	GC	LC	GC	VC	GC
MC	0	HC	0	LC	0	LC	0	VC	0
MC	MC	HC	GC	LC	LC	LC	LC	VC	VC
MC	MC	HC	GC	LC	LC	LC	LC	VC	VC
MC	HC	HC	HC	LC	MC	LC	LC	VC	VC
MC	GC	HC	HC	LC	MC	LC	MC	VC	LC

MC	HC	HC	GC	LC	MC	LC	LC	VC	VC
MC	GC	HC	0	LC	HC	LC	MC	VC	LC
MC	HC	HC	GC	LC	MC	LC	LC	VC	VC
MC	MC	HC	GC	LC	LC	LC	LC	VC	VC
MC	GC	HC	GC	LC	LC	LC	LC	VC	VC
MC	MC	HC	HC	LC	MC	LC	LC	VC	VC
MC	HC	HC	MC	LC	LC	LC	LC	VC	VC
MC	0	HC		LC		LC		VC	
MC	GC	HC	GC	LC	MC	LC	MC	VC	LC
MC	MC	HC	GC	LC	LC	LC	LC	VC	VC
MC	MC	HC	HC	LC	MC	LC	LC	VC	VC
MC	MC	HC	HC	LC	LC	LC	MC	VC	VC
MC	HC	HC	HC	LC	GC	LC	GC	VC	MC
MC	MC	HC	HC	LC	MC	LC	LC	VC	VC
MC	MC	HC	HC	LC	LC	LC	MC	VC	VC
MC	GC	HC	HC	LC	LC	LC	0	VC	VC
MC	MC	HC	0	LC	0	LC	0	VC	0
MC	MC	HC	GC	LC	LC	LC	LC	VC	VC
MC	GC	HC	MC	LC	LC	LC	VC	VC	NC
MC	MC	HC	GC	LC	LC	LC	LC	VC	VC
MC	GC	HC	HC	LC	LC	LC	LC	VC	VC
MC	GC	HC	HC	LC	MC	LC	MC	VC	LC
MC	MC	HC	HC	LC	MC	LC	LC	VC	VC

MC	HC	HC	HC	LC	MC	LC	LC	VC	VC
MC	GC	HC	HC	LC	MC	LC	GC	VC	LC
MC	GC	HC	HC	LC	LC	LC	LC	VC	VC
MC	GC	HC	HC	LC	LC	LC	MC	VC	VC
MC	GC	HC	HC	LC	MC	LC	MC	VC	LC
MC	GC	HC	HC	LC	GC	LC	LC	VC	VC
MC	GC	HC	HC	LC	MC	LC	VC	VC	NC
MC	MC	HC	HC	LC	LC	LC	LC	VC	VC
MC	HC	HC	GC	LC	MC	LC	MC	VC	LC
MC	MC	HC	HC	LC	MC	LC	LC	VC	VC
MC	MC	HC	HC	LC	LC	LC	LC	VC	VC
MC	MC	HC	HC	LC	MC	LC	LC	VC	VC
MC	GC	HC	MC	LC	LC	LC	MC	VC	GC
MC	MC	HC	HC	LC	MC	LC	LC	VC	VC
MC	HC	HC	GC	LC	MC	LC	MC	VC	MC
MC	GC	HC	GC	LC	MC	LC	GC	VC	LC
MC	MC	HC	0	LC	0	LC	0	VC	0
MC	MC	HC	GC	LC	MC	LC	MC	VC	VC
MC	GC	HC	GC	LC	HC	LC	GC	VC	LC
MC	HC	HC	HC	LC	MC	LC	MC	VC	VC
MC	GC	HC	HC	LC	MC	LC	LC	VC	VC
MC	GC	HC	GC	LC	MC	LC	MC	VC	VC
MC	HC	HC	GC	LC	MC	LC	LC	VC	NC

MC	HC	HC	HC	LC	MC	LC	MC	VC	VC
MC	GC	HC	HC	LC	LC	LC	LC	VC	VC
MC	MC	HC	GC	LC	MC	LC	LC	VC	VC
MC	GC	HC	HC	LC	MC	LC	LC	VC	VC
MC	HC	HC	HC	LC	GC	LC	MC	VC	LC
MC	MC	HC	VC	LC	VC	LC	MC	VC	VC
MC	MC	HC	HC	LC	LC	LC	GC	VC	VC
MC	HC	HC	HC	LC	MC	LC	LC	VC	VC
MC	MC	HC	HC	LC	MC	LC	MC	VC	VC
MC	MC	HC	HC	LC	LC	LC	LC	VC	VC

Table I.3: Mod-SYMLOG Chapter 5 Experiment 3 Diagrams Only

How easy did you find using totals ONLY for assessing group co-operation?	How easy did you find using node diagrams ONLY for assessing group co-operation?	How easy did you find using both totals and node diagrams for assessing group co-operation?	Would you prefer only to see negative connections between students?	If you were a teacher or a team leader, would you find these node diagrams useful for supporting your students/team?
5	7	2	3	1
3	3	6	2	2
0	0	0	0	0
0	0	0	0	0
7	4	3	1	1
1	2	3	2	1
1	1	1	4	2
6	3	5	1	1
2	5	2	3	3
6	4	4	3	2
4	6	6	4	2
4	1	4	4	2

7	6	3	1	2
2	3	3	2	2
5	4	3	2	1
1	7	6	0	3
5	5	2	2	1
2	2	2	3	2
2	5	3	4	3
4	5	5	1	3
7	6	5	3	1
7	5	5	3	2
4	6	6	4	6
7	5	6	3	3
7	6	5	3	3
2	5	5	2	2
7	7	5	4	2
2	6	5	4	6
4	5	5	1	2
2	3	3	4	3
3	3	3	2	3
2	2	1	4	2
7	5	2	3	2
7	5	1	2	3
5	1	3	2	2

7	6	3	2	1
7	1	1	2	1
2	5	5	2	5
1	2	1	1	1
4	2	2	1	3
2	5	5	2	5
2	5	5	2	5
3	3	1	3	5
1	5	2	3	1
6	5	3	4	3
1	6	8	1	4
2	5	2	4	5
6	3	2	2	1
7	2	4	2	2
2	2	1	3	1
3	6	6	1	5
6	3	2	2	2
5	5	5	3	4
5	3	3	4	5
6	7	3	2	2
3	4	5	2	4
8	8	4	3	4
7	4	3	3	5

6	3	1	3	2
7	6	3	2	1
6	6	5	3	2
5	4	6	2	2
2	2	3	4	5
7	5	3	3	5
3	4	3	3	3
0	0	0	0	0
0	2	3	3	5
0	2	3	3	5
1	6	3	3	3
2	3	1	2	1
1	2	1	2	1
2	0	1	2	1
1	4	5	1	5
5	3	2	2	2
5	5	3	2	3
7	6	3	3	4
5	5	3	2	3
6	3	1	1	1
1	4	4	1	3
2	2	3	4	2
2	3	3	2	2

1	2	3	1	6
7	6	3	3	2
6	7	3	3	5
3	3	4	2	2
3	3	2	2	2
6	5	4	4	0
2	5	1	2	1
2	5	1	2	1
2	3	2	1	5
3	6	5	3	3
1	5	3	1	5
1	3	5	3	2
6	6	1	3	1
1	3	2	4	5

Table I.4: Mod-SYMLOG Chapter 5 Experiment Questionnaire

Appendix J

Mod-Snowdrift Experiment 3 comments

J.1 Mod-Snowdrift Experiment 3 Comments

No.	Comment

1	The first part does not involve the necessary information about the quality of the cooperation (i.e., money exchange). It was easy, but not useful. Only diagram condition helps you get the correct answer, but it takes time to calculate the total amount of money dedicated by students. I would therefore not use only diagrams or only money information as they slow down or hamper the assessment. Last, I selected ”helpful” for the last question, but it is conditional that diagrams would be supported with total money information. Otherwise I am not sure whether I would find it useful.
2	Good luck.
3	It was a bit difficult to understand the instructions for both the “grading rubric” that we were meant to use, and then for the node diagrams. It was unclear whether we should be counting the nodes (students) who gave 0 pounds or the edges representing 0-pound-donations. Therefore, there was a learning curve throughout the experiment, which might inevitably lead to the third stage having the highest accuracy. It would be immensely helpful to be shown some examples of the rubric applied to some scenarios before we the subjects are expected to implement it!
4	It’s quite confusing on what judge based solely on the amount of money on the pot alone, whilst with the only node diagram alone, it can simply direct judge without other variable involved.

5	Somehow with the mixture for both, I found that it's quite difficult to make any judgement and balancing the result based ob both data.
6	Great work b
7	Felt mostly the subject not the participant. Wtf is snowdrift etc? 'Inculding' is used consistently. Following rules was hard to impossible but spelling and grammar were sloppy creating frustration and trust collapse. This box is too small for me to list all the issues I have with this both on a theoretical and execution viewpoint.
8	Düğüm diagramları öğrenciler arasındaki iş birliğini görsel olarak sunduğu için bu diagramlar öğretmenlerin yanısıra öğrencilerin de aralarındaki ilişkiyi somut olarak görebilmelerini sağlaması sebebiyle oldukça yararlıdır. (Translation via Google Translate: Since the node diagrams visually present the cooperation between students, these diagrams are very useful as they enable students as well as teachers to see the relationship between them in a concrete way.)
10	The Totals only was easiest to use, but not if you want the correct answer about cooperation. That is why I rated it very difficult.
11	The students could coach themselves if they want to, assuming they have their own results.

12	Seeing the colours on node diagram immediately gave me feedback on cooperation levels. Having the £ info made me realise that the £ figure is not the most important criteria. Having £ and diagram was invaluable.
13	2. Ve 3. Deneylerde rengi değiştir seçeneği tıklanınca yazılar İngilizce olup para biri sterline döndü. TL den farklı olması için miydi yoksa fark edilmeyen bir sorun mu bilemiyorum. Başarılar... (Translation via Google Translate: When the change color option was clicked in the experiments, the texts were in English and the money turned into a pound sterling. I do not know if it was to be different from TL or if it was an unnoticed problem. Achievements...)
14	I would likely, in this specific case, find useful totals of how many in each group paid what. I would then probably use that list, as opposed to parsing it from the diagram.
15	The links were too complicated to follow. An overall visual image was always much more better to understand the output.
16	diagram showing totals and cooperation lines extremely useful - it is too easy to make assumptions based on total alone
17	Diagram düğümleri ve toplam grup puanları nasıl oluşturulduğuna dair, daha fazla bilgi verebilirsiniz. (Translation via Google Translate: You can provide more information on how to create diagram nodes and total group scores.)

18	The nod questions were not easy for a layman to understand. I needed someone to explain them.
19	Higher resolution imagery, wording could be more simplified.
20	I am color blind, having difficulty choosing colors ...
21	supply count of connection types
22	too many typos

Table J.1: Experiment 3: Comments