Modelling the Effects of Personality and Temperament in Small Teams

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Abstract. We present an investigation into the effects that player personality can have on team performance in games that have been designed to have a social purpose ("serious games"), such as games intended to enhance more consideration for the environment and for sustainable energy usage. The work involves multi-agent-based model of team play, where individual player personalities are characterized by Myers-Briggs Type Indicator (MBTI), which specifies personality according to several psychological categories. This includes a fuzzy-logic-based MBTI parameterization of player personality. Experiments employing agent-based simulation are then presented that show the effects of various combinations of personality and temperament types on team performance in the context of competing team profiles. Modelling of this nature can generally be used by policy makers in connection with the recruitment of project teams that are likely to work together more effectively.

Keywords: Agent-based simulation · Myers-Briggs type indicator · MBTI · Fuzzy logic · Serious games · Performance · Team-work

1 Introduction

In many project tasks, teamwork plays a vital role for getting things done and the efficiency of the results. Effective teamwork is one of the predictors of organizational success, since it can cause rapid information exchange and increase responsiveness [1]. Interactions among members of a group can generate social support, sharing of work and cooperation [2].

Previous research considered various factors in teamwork such as skills, gender, leadership as well as knowledge, experiences, and age. Some of them emphasise specially the importance of personality as predictor of peoples' behaviour [3].

There are various mechanisms to analyze team performance. Some researchers suggest team members do not perform uniformly in team processes and they analyze how individuals contribute to teamwork. Nevertheless, they believe that such contributions to the team process can still be described by individual-level activities [4] and most of them consider team composition as a predictor of team performance. Team composition here refers to the configuration of members that have a significant influence on team process and outcomes [5]. In this paper, both level of analysis are

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taken into consideration and individual attribute of teams and team composition are both considered to affect team performance.

The empirical examination of how team composition affects performance would normally require large data samples collected over nontrivial time periods, and such data are not easily obtained [6]. In order to assist in this analysis, we believe that virtual worlds and computer-assisted game environments can provide platforms for analysing teamwork [7]. So our goal here is to demonstrate the usefulness of a simulation model that can be used to examine how various player performance profiles can influence overall team behaviour.

In fact our longer-term goal is to investigate how game procedures can encourage human behaviour that contributes to the common good, which is sometimes called "green behaviour". Games that can encourage such green behaviour are called "serious games".

Although, in general, some of the most popular games are those in which a single user tries to achieve a high score by playing against a machine, we believe that team-oriented games are more naturally suited to induce the desired collaborative and cooperative attitudes necessary for improved "green" behaviour. However, team games are more difficult to design so that they have the appropriate compelling gameplay and cannot be dominated by a single player. In this respect, one doesn't want a game that is dependent on the skill of the most talented player – rather, one wants a game that is likely to be won by the team that employs the most teamwork. So the individual game activities in this kind of game should not be particularly difficult or demanding. What should matter is the teamwork.

To assist the team-oriented game designer, we have constructed an agent-based model of a "serious game" in order to examine how various mechanisms affect game performance. In the work presented here we are particularly interested in the issue of teamwork and how the different player "personalities" can affect the team performance in the game. Although our focus here is on gameplay, our study of personality influence on team effectiveness applies to project teamwork in general. As such the work can be used to support improved policy-making in connection with project team composition.

2 Player Personality and Performance

Understanding human personality and its effect on performance is an enormous subject in itself, and we do not pretend to treat this subject in all its depth here. Nevertheless, there are some commonly held notions concerning variations of human temperament and personality that have been developed over the past century, and we take advantage of some of them. Carl Jung developed an initial scheme of psychological type, which included the notion of introversion and extroversion [8]. Myers added additional elements to this arrangement [9], and it has evolved into what is now referred to as the Myers-Briggs Type Indicator (MBTI) scheme [10].

According to the MBTI scheme, there are four "dimensions" of human personality:

- **E**xtraversion vs. **I**ntroversion – the degree to which one faces the outer social world or keeps more to him or herself.
- **S**ensing vs. i**N**tuition – the degree to which one gathers information that is in concrete, objective form or is more abstract and understood according to one's inner compass.
- **T**hinking vs. **F**eeling – the degree to which one makes decisions based on logic and demonstrable rationality or is more empathic and attempts to see things from given perspectives.
- **J**udgmental vs. **P**erceptive – the degree to which one wants to come to quick, categorical decisions or is more inclined to withhold judgement for the time being.

An individual can then be indexed according to one of sixteen possible types. For example a person identified as INFP is introverted, intuitive, feeling, and perceptive.

Although the scientific accuracy of the MBTI scheme may be questioned, and there have been other alternative personality categorization schemes that partitioned people into a small set of types, such as "Big Five" (aka OCEAN) [11] and Temperament theory [12], the MBTI scheme is the most well-known. In addition, there are several accessible and publicly-available MBTI instruments for categorizing people according to this scheme, and we have found them to be relatively reproducible in connection with our own experiments. So we believe that the MBTI measure can be a potentially useful yardstick to distinguish game players in terms of their game personalities. And this is what we use to guide our initial agent-based game designs. We also employed Temperament theory that is related to the MBTI scheme, indeed a pared-down version of it. Temperaments can be considered to be aggregations of MBTI types into smaller groups according to Table 1.

Table 1. Temperament theory

Temperament	MBTI types
Duty seeker	ESFJ, ISFJ, ESTJ, ISTJ (JS)
Knowledge seeker	ENTP, INTP, ENTJ, INTJ (NT)
Action seeker	ESFP, ISFP, ESTP, ISTP (SP)
Ideal seeker	ENFP, INFP, ENFJ, INFJ (NF)

3 Structure of Environment

We constructed some games involving four-member teams that would engage in various tasks involving environment-enhancing activities. Teams would draw mission "cards" that stipulated the tasks to be performed, and then the team would have to go out and perform the tasks. All the tasks require group cooperation. The basic sequence of gameplay is shown as a flowchart in Fig. 1.

In our game environment we considered two types of tasks:

- **Structured tasks:** those are not complex. These tasks require individual team members to use less cognitive recourse and they have specific question and specific answers.

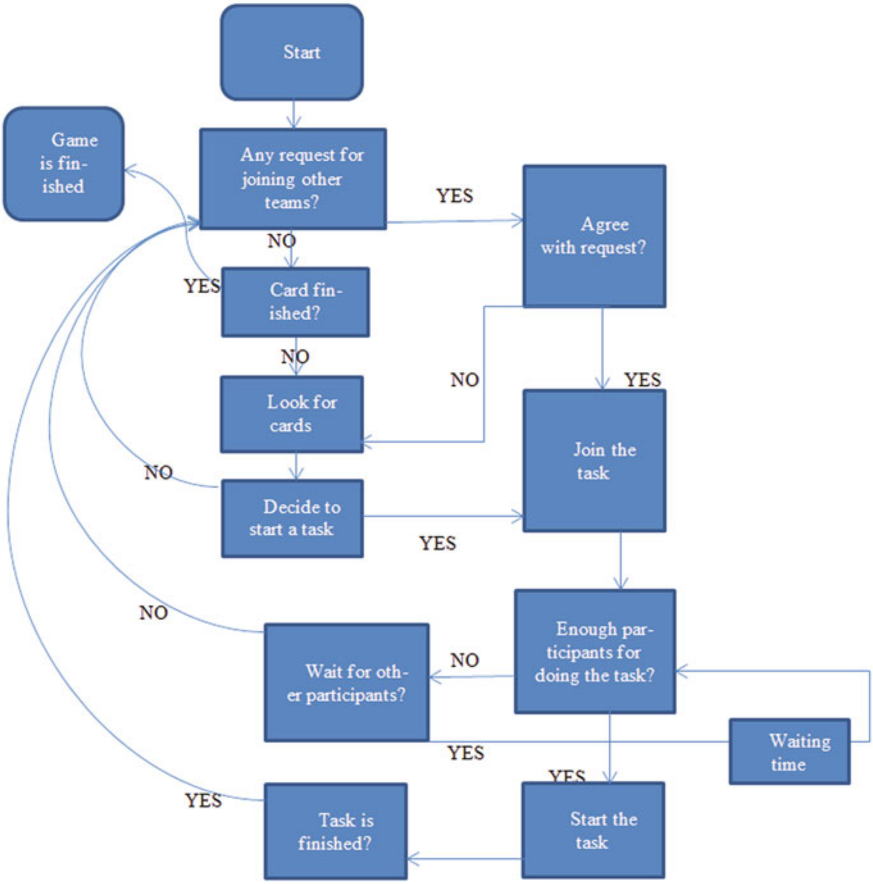

Fig. 1. Game flowchart

- **Open-ended:** or 'cognitive', tasks that require relatively more creativity and imagination.

Some examples of open-ended and structured tasks are shown in Table 2.

The effectiveness of a team's performance in these types of projects or games can be strongly influenced by the personality makeup of the team. In our work, we have developed a model that shows how team personality composition is related to team performance during serious games. The modelling approach outlined in this research can be of use for policy makers whose aim either is fostering sustainability via behaviour change or is simply discovering what is the most effective team composition. The model can also be used to recruit team members of certain personality in order to perform certain type of tasks.

Figure 1 illustrates how our game works. This is from one agent's point of view and describes how it starts a task or forms a group and performs the tasks during the game. In Sect. 3.1–3.4, we show how personality types, as indicated by MBTI measures, can collectively affect team performance.

Table 2. Tasks on mission cards

Open ended task	Structured task
Host and participate in an event for lunch and have a short tutorial about healthier food	Check different kind of bins (paper, compost, plastic and trash bins) and make sure waste goes to proper bins. Teams can compete together and gather as much waste as they can
Present survey results about sustainable issues	Fill assessment sheets to assess sustainability in different parts of the town
Start a recycling program	Tree-planting event
Express sustainability issues through arts and crafts	Teams put out some bins in the city for second hand clothes or other sharing items
Film current sustainable projects and activities and upload to Internet	Offering waste reduction tips for consumers
Run an event for swapping second hand clothes	Gathering donations for non-profit green organizations

3.1 Personality and Information

Intuitive people (MBTI: N, as opposed to S) focus on the big picture and look for overall patterns, rather than focussing on details. They are looking for something larger than just the current activities. In contrast, sensing people (S) prefer to collect all the immediate information around them. So they spend more time tracking than doing [10]. Therefore we assume that in games, intuitive (N) people are faster overall in making up their mind for doing a new task than sensing people (S), who may need more time to know all the information about that task.

3.2 Personality and Interaction

In connection with thinking and feeling (the F-T dimension of MBTI), feeling people are more likely to be concerned about the impacts of their decisions in connection with their social context. Thinkers follow their objective principles and standards that are less influenced by context [10]. Therefore T-people are logical, and F-people make decisions based on their heartfelt concerns.

Moreover, when it comes to joining up to make a team, the sociability of a person can be a factor. This is the I-T (introversion vs. extraversion) dimension of MBTI. Extraverts are energized by interacting with others, and so they prefer to work in groups. Introverts prefer to work alone to get things done. As a result, we assume having high feeling and extroverted personality has a positive effect on a player's decision to interact with others. These factors affect players' behaviour for asking others to join them and also replying others' request to join the task.

3.3 Personality and Flexibility

After players decide to start a task, they send requests to others to join them. In this stage, the judgmental vs. perceiving aspect of one's personality (the J-P dimension of the MBTI scheme) comes into play. Judgers (J-people) prefer to operate in a planned and settled fashion, while perceivers (P-people) can operate in a more flexible and spontaneous way – they prefer to remain open to new information that may come in at any time [10]. Therefore, we assume J-people are more likely to wait longer for others to join them, whereas P-people may leave a task in order to opportunistically pursue a new task.

3.4 Personality and Team Performance

During task activities, a team's personality composition strongly influences success in finishing a task. To model this aspect of team performance, we investigated the degree to which differing personalities can work together effectively as a team. So we examined (a) single team metrics that quantify certain aspects of team composition as well as (b) a more detailed examination of team composition with respect to a new individual team member parameter. In this connection, we introduce two additional indicators [13] that are used in conjunction with the MBTI measures:

- Team Personality Elevation (TPE): a team's mean level for a particular personality trait;
- Team Personality Diversity (TPD): the variance with respect to a particular personality trait among team members.

With respect to TPE, we make the following observations.

- A high TPE in sensing (S) is presumed to have a positive effect on structured tasks. Recall that MBTI Sensing and iNtuition concern how people gather information. Sensing people are fact-driven and prefer to develop a single idea fully [14].
- A high TPE in judging (J) is also taken to have a positive effect on structured tasks. People high in judging prefer to live according to plan, and avoid extended periods of doubt. Some research has confirmed the positive relationship between conscientiousness and team performance for pooled tasks [15].
- A high TPE in intuition (N), however, has a positive effect on open-ended tasks. Intuitive people are imaginative and creative. They tend to think about several things at the same time and make connections between them.
- A high TPE in feeling (F) has a positive effect on both open-ended and structured tasks. Feeling can lead to greater cohesion among team members. Some research has shown that 'agreeableness' from the Big Five model, which is correlated with feeling in the MBTI model, has a positive effect on team performance [16]. In the connection with 'green' activity, feeling is expected to play a significant role, because green actions support the activities of others; and F-people try to meet the needs of others, even at the expense of their own needs.
- A high TPE in thinking (T) can have a positive effect on structured tasks. Thinkers follow rationally-derived procedures, which conform well with structured tasks [17].

With respect to TPD, we make some further observations.

- A high TPD in the judgmental-perceiving (J-P) domain has a positive effect on open-ended tasks. A perceiver is flexible and often finds new ways to do things, but at the same time they sometimes dwell on the task work at the expense of reaching closure [18]. Overemphasis on judgment in complex tasks might lead premature completion of the project with limited achievement; while overemphasis on perceiving might lead to interim successes without final task completion. Therefore it might be good to have a team with a mixture of judgers and perceivers. Some research has shown that a variation in conscientiousness on a team can have positive effects in connection with the performance of intellectual and analytical tasks [19].
- Low TPD in the sensing and intuition (S-N) domain can have a positive effect on structured tasks. The literature suggests that homogeneity in this area tends to benefit teams in connection with tasks that are well-defined. Homogeneity in this area can have two main beneficial consequences: integration and conflict avoidance [20]. This is because highly intuitive (high N) people are self-directed and know what they want, which can make sensing people (high S) frustrated.
- However, a high TPD along the sensing-intuition (S-N) axis is believed to have a positive effect on open-ended tasks. Having a balance in this connection can be advantageous, because high intuition can see the big picture, and high sensing can then put the derived concept into action [21].
- A low TPD along the feeling-thinking (F-T) axis is expected to have a positive effect on both open-ended and structured task performance. A disparity on a team with respect to feeling and thinking can conflict with the decision-making process. In that case some of the team members are concerned with the longer-term impacts of their decisions, while others are focused on the immediate pros and cons of the decisions. Research with respect to the Big Five category of ‘agreeableness’, which is thought to correspond to the MBTI F-T axis, suggests that homogeneity with respect to agreeableness has a positive effect on team performance [22].
- A high TPD along the extraverted-introverted axis (E-I) is expected to have a positive effect on both structured and open-ended tasks. Extraverts increase team communication, but too many of them may be deleterious and lead to a decreased focus on getting the job done [13].

The rules for team performance are based on assumptions which were described earlier. Accordingly, some factors affect performance of structured tasks (we abbreviate the given effect by using the numbered letters shown in parentheses) – such as TPE in sensing (S1), TPE in judging (S2), TPE in feeling (S3), TPE in thinking (S4), TPD in sensing and intuition (S5), TPD in feeling and thinking (S6), and TPD in extraverted and introverted (S7). Factors affecting performance in open-ended tasks included TPE in intuition (O1), TPE in feeling (O2), TPD in judging and perceiving (O3), TPD in sensing and intuition (O4), TPD in feeling and thinking (O5) and TPD in the extraverted and introverted category (O6). These factors are crucial for agents to estimate the probability of performing the task successfully in each attempt.

Rules were then constructed for structured tasks and open-ended tasks. Two of them are exampled here:

IF the task is Open-ended AND O1 is high AND O2 is high AND O3 is high AND O4 is high AND O5 is high
THEN Performance is very high
IF the task is Structured AND S1 is high AND S2 is high AND S3 is high AND S4 is high AND S5 is high AND S6 is high
THEN Performance is high

Such fuzzy rules are executed for each team to show their performance in structured and open ended tasks.

3.5 Fuzzy Model

Because we are constructing an agent model of players who make decisions with respect to imprecisely-known information, the agents employ a fuzzy-reasoning decision model [23]. In this respect the agents deal with information that can have a fuzzy membership value with respect to their categorization. Thus, for example considering size, something could be considered to be both medium-sized (to a certain degree by having a fuzzy membership value between 0 and 1) and large (also with a fuzzy membership value between 0 and 1).

The fuzzy logic we employ is based on Takagi-Sugeno-Kang (TSK) fuzzy inferencing [24], which is similar to Mamdani fuzzy inferencing [25] but has advantages with respect to computational efficiency. The general form of TSK method which is employed in this work presented as follows:

$$\textbf{IF}\, x_1 \text{ is } A_{1,r} \text{ and } \ldots \text{ and } x_p \text{ is } A_{p,r}\, \textbf{THEN}\, y_r = f_r(x_1, x_2, \ldots x_p) \tag{1}$$

where

$A_{p,r}$ is a partitioned domain of the input variable x_p in the r_{th} If-Then rule,

p is the number of input variables, and

y_r is the output variable in the r_{th} If-Then rule.

It is assumed that there are $R_r(r = 1, 2, \ldots, n)$ and for each implication of R_r, we have

$$y_r = f_r\left(x_1, x_2, \ldots\ldots x_p\right) = b_{0,r} + b_{1,r}x_1 + \ldots, b_{p,r}x_p \tag{2}$$

where $b_{0,r}, \ldots, b_{p,r}$ are consequents of the input variables that specify the variables involved in the r_{th} rule's premise.

The weight of input variables is calculated as following:

$$r_r = T(\mu_{A_{1,r}}(x_1), \ldots, \mu_{A_{p,r}}(x_p)) \tag{3}$$

where T is the minimum *t-norm* which is recommended by Mamdani and called the Godel t-norm that can be presented as following.

$$r_r = \min\{\mu_{A_{1,r}}(x_1), \ldots, \mu_{A_{p,r}}(x_p)\} \tag{4}$$

The final output y inferred from n implications is given as the average of all the weights r_r:

$$y = \frac{\sum_{r=1}^{n} r_r \times y_r}{\sum_{r=1}^{n} r_r} \quad (5)$$

To illustrate, in one stage of task activity, agents must decide to start a task or not, which will depend on the degree of extraversion and feeling in the personality. Here the input is the degree of one's extraversion and feeling, and the output is the level of confidence about starting a new task, which can be "quite interested", "interested" and "not interested". Membership function of feeling and extraverted is illustrated in Figs. 2 and 3. The sets related to the linguistic variable "feeling" and "extraverted" are those representing membership grades to fuzzy sets shown in Table 3:

The use of linguistic rules in combination with fuzzy inference can then serve as an effective knowledge base for analysis of action (see Figs. 4 and 5). Consider the nine fuzzy rules shown in Table 4.

The nine fuzzy rules for this activity are shown in Table 4:

In this example we assume crisp input data for the degrees of *feeling* and *extravertedness*. Let us consider a situation where Feeling = 70 and Extraversion = 45, According to Table 3 then the feeling will be considered to be *medium* with a degree $\mu_{feeling-medium}(70) = 0.6$; and it will be considered to be *high* with a degree $\mu_{feeling-high}(x) = 0.4$. Extraversion here is considered to be *low* with $\mu_{extraverted-low}(45) = 0.2$, and it is considered to be *medium* with $\mu_{extraverted-medium}(45) = 0.8$.

Four activated rules for these sets can be found in Table 4: R2, R3, R5, R6. We employ the zero-order TSK method, where the output of each fuzzy rule is constant, and all consequent membership functions are represented by a singleton spike. In this case each output is a constant number representing an agent's interest to start a task.

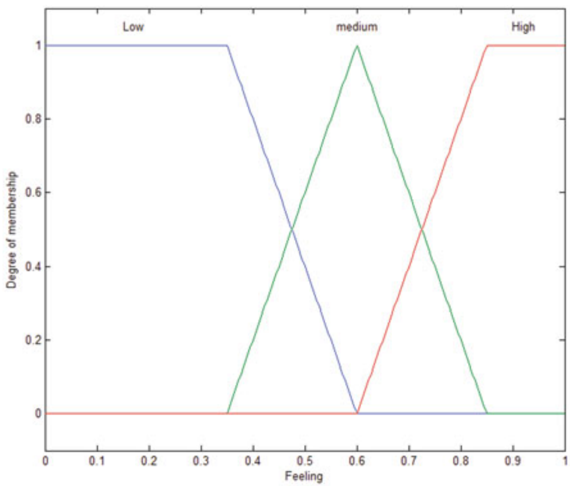

Fig. 2. Membership function for feeling

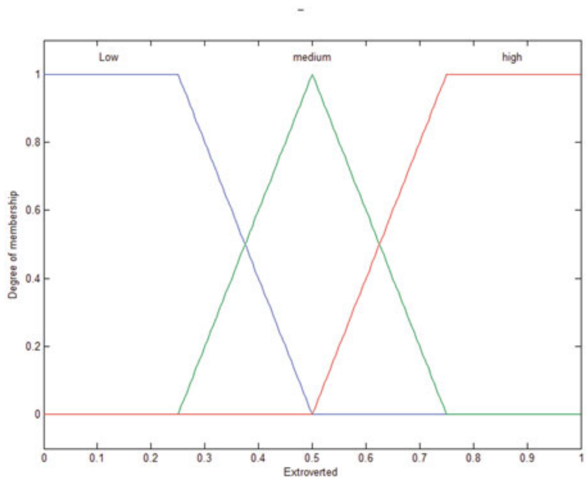

Fig. 3. Membership function for extraverted

Table 3. Membership grades

The characteristic functions of the sets reacted to linguistic variable *feeling* are:	The characteristic functions of the sets reacted to linguistic variable *extraverted* are:
$\mu_{feeling-low}(x) = \begin{cases} 0 & x > 60 \\ \frac{60-x}{60-35} & 35 \leq x \leq 60 \\ 1 & x < 35 \end{cases}$	$\mu_{extroverted-low}(x) = \begin{cases} 0 & x > 50 \\ \frac{50-x}{50-25} & 25 \leq x \leq 50 \\ 1 & x < 25 \end{cases}$
$\mu_{feeling-medium}(x) = \begin{cases} 0 & x \leq 35 \\ \frac{x-35}{60-35} & 35 < x \leq 60 \\ \frac{85-x}{85-60} & 60 < x < 85 \\ 0 & x \geq 85 \end{cases}$	$\mu_{extroverted-medium}(x) = \begin{cases} 0 & x \leq 25 \\ \frac{x-25}{50-25} & 25 < x \leq 50 \\ \frac{75-x}{75-50} & 50 < x < 75 \\ 0 & x \geq 75 \end{cases}$
$\mu_{feeling-high}(x) = \begin{cases} 0 & x < 60 \\ \frac{x-60}{85-60} & 60 \leq x \leq 85 \\ 1 & x > 85 \end{cases}$	$\mu_{extroverted-high}(x) = \begin{cases} 0 & x < 50 \\ \frac{x-50}{75-50} & 50 \leq x \leq 75 \\ 1 & x > 75 \end{cases}$

“quite interested” $= 75 = k_1$; “interested” $= 50 = k_2$; “not interested” $= 10 = k_3$
And by using formula (4):

$$r_2 = \min\{\mu_{feeling-high}(x), \mu_{extroverted-medium}(45)\} = 0.4 \tag{6}$$

$$r_3 = \min\{\mu_{feeling-high}(x), \mu_{extroverted-low}(45)\} = 0.2 \tag{7}$$

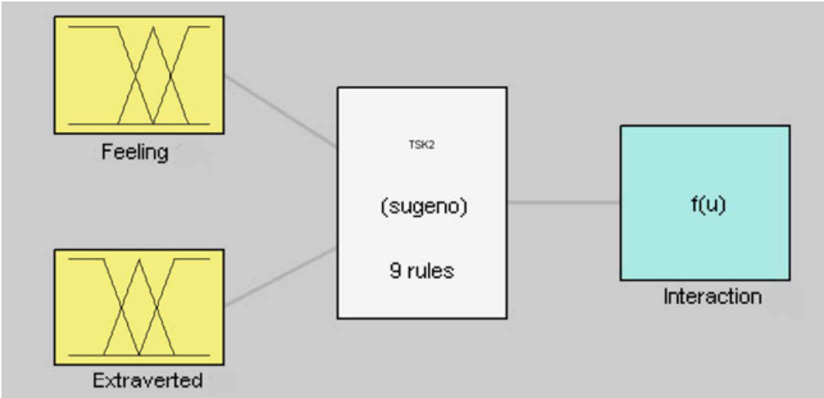

Fig. 4. The fuzzy inference system estimates the probability of interaction with other teammates.

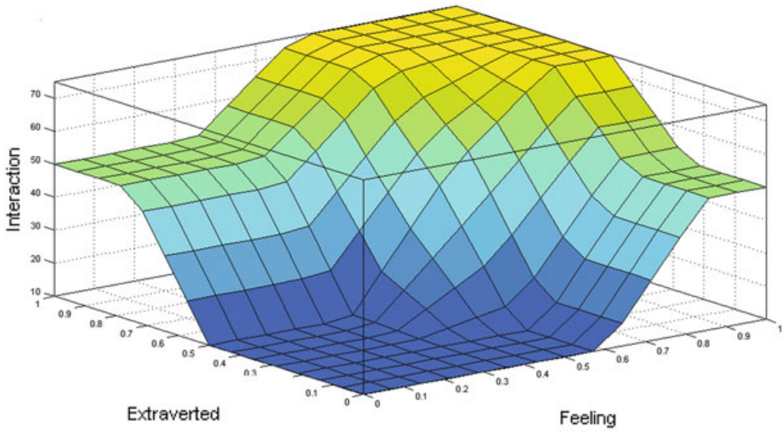

Fig. 5. Fuzzy surface *Feeling*, *Extraverted* and *Interaction.*

Table 4. Fuzzy rules about interaction

IF	*Feeling*	AND	*Extraverted*	THEN	*Interaction*
R1	High		High		Quite Interested
R2	High		Medium		Quite Interested
R3	High		Low		Interested
R4	Medium		High		Quite Interested
R5	Medium		Medium		Interested
R6	Medium		Low		Not Interested
R7	Low		High		Interested
R8	Low		Medium		Not Interested
R9	Low		Low		Not Interested

$$r_5 = \min\{\mu_{feeling-medium}(x), \mu_{extroverted-medium}(45)\} = 0.6 \tag{8}$$

$$r_6 = \min\{\mu_{feeling-medium}(x), \mu_{extroverted-low}(45)\} = 0.4 \tag{9}$$

And by using formula (5)

$$Z = \frac{r_2k_1 + r_3k_2 + r_5k_2 + r_6k_3}{r_2 + r_3 + r_5 + r_6} = 62.5 \tag{10}$$

The value of Z denotes the probability of an agent starting a new task (i.e. 0.625 in this case). This process is illustrated in Fig. 3.

4 Experiments

Experiments have been implemented in NetLogo [14]. We assigned a random number between 0 and 100 for each personality as follows:

- Extraverted/introverted: (range 0–50 → *introverted*; 50–100 → *extraverted*).
- Sensing/intuitive: (range 0–50 → *intuitive;* 50–100 → *sensor*),
- Feeling/thinking: (range 0–50 → *feeler;* 50–100 → *thinker*),
- Judging/perceiving: (range 0–50 → *perceiver;* 50–100 → *judger*).

We then conducted agent-based simulations with teams assigned to complete green-oriented tasks. Four teams compete against each other to find and finish the tasks. Teams received a score based on the tasks that they completed. The following algorithmic steps for agent behavior involving the use of fuzzy rules were then employed:

1. Stochastic values for personality were assigned to each agent. The values are then used to assign fuzzy membership.
2. Agents look for mission assignment cards in their neighborhood.
3. Agents find the card. If they are *Sensor* wait for a few seconds to know all the information about the tasks otherwise – *intuition* agents-make their mind very fast.
4. Agents make their decisions whether start the task. The alacrity of this decision is influenced by the degree to which have *feeling* and an *extraverted* personality.
5. When an agent finds a task, it invites other teammates to join it. At least two agents are needed for starting a task. (Again they accept or decline a request according to their (fuzzified) interests in starting a task as determined by feeling/thinking and extraverted/introverted personalities).The score desponds on the number of agents in a team. If four members of team do a task successfully they score one. In the cases that fewer agents finish a task successfully, the scores for two and three agents are 0.5 and 0.75 respectively.
6. If the minimum number of teammates is not achieved, then the recruiting agent waits for a short time and repeats its request. (The duration that they wait for others is limited and depends on its *judging/perceiving* personality - Judgers wait longer.)

7. After the agents start a task, we use personality composition measurements to see how they perform during the task. *TPE* and *TPD* of the group members who are working on a task are computed. TPE is the mean of each personality and TPD is the standard deviation of each personality. After fuzzification and applying the rules the performance of teams are determined. Diffuzification determines the probability of finishing the tasks.

5 Results

The simulation study examined all 3876 (all the possible combinations of four personalities among 16 personalities for four team members) MBTI team combinations in a four-team competition. The average scores in terms of number of tasks completed for the various MBTI types are shown in the Tables 4 and 5. With respect to the results and the computed scores, we note the following:

- An individual experimental run involved teams whose members had randomly selected MBTI personalities working on the completion of 200 tasks (100 open-ended and 100 structured), which usually took about 10,000 time steps. These runs were repeated 65,000 times with different randomly selected team-personality makeups in order to ensure that all possible personality combinations occurred. The score for each team combination was calculated based on the average number of tasks that that team completed successfully.
- All the 3876 possible combinations are ranked for structured and open-ended tasks based on their average scores.
- The aggregated average performance for each individual personality in the overall team scores is shown in Tables 5 and 6.
- For the purposes of further demonstrating the aggregated results, the teams were also classified according to their temperament makeups based on the MBTI classifications of temperaments presented in Table 1. The average scores of the 35 possible temperament combinations for teams are presented in Table 7.

Table 5 shows that flexibility has some merit for open-ended tasks. Since most of them with personality with P (Perceivers) generally did better than those with J (Judgers). In structured tasks Judgers did slightly better than Perceivers because of their positive role during performance of tasks. In Fig. 6 performance of each personality for open ended and structured tasks are compared.

Table 5. Personality ranking for open ended tasks

Personality	ENFP	INFJ	INFP	ENFJ	ISFP	ESFJ	ENTP	ESFP	ESTP	ENTJ	INTP	ISFJ	ISTP	ISTJ	ESTJ	INTJ
Score	35	34	34	34	31	30	30	28	28	27	23	22	19	19	15	14

Table 6. Personality ranking for Structured tasks

Personality	ESFJ	ENFP	ISFJ	ESFP	ENFJ	ENTJ	INFJ	ESTJ	ESTP	ENTP	ISFP	INFP	ISTJ	INTJ	INTP	ISTP
Score	46	41	40	39	39	35	34	31	30	27	26	25	25	23	18	17

Table 7. Ranking of combinations in structured task and open-ended tasks

Rank	Structured				Score	Rank	Open-ended				Score
1	Ideal	Ideal	Ideal	Ideal	21.86	1	Ideal	Ideal	Act	Act	17.14
2	Duty	Duty	Duty	Duty	21.81	2	Ideal	Ideal	Act	Duty	17.12
3	Duty	Duty	Duty	Act	19.67	3	Duty	Ideal	Act	Knw	17.07
4	Act	Duty	Duty	Act	18.65	4	Ideal	Act	Act	Knw	16.72
5	Ideal	Ideal	Ideal	Knw	17.73	5	Knw	Knw	Act	Duty	16.7
6	Act	Duty	Act	Act	17.35	6	Knw	Knw	Act	Act	16.37
7	Ideal	Duty	Duty	Duty	17.34	7	Duty	Duty	Ideal	Ideal	16.13
8	Ideal	Duty	Ideal	Ideal	17.24	8	Duty	Ideal	Duty	Knw	15.97
9	Act	Act	Act	Act	16.51	9	Duty	Ideal	Act	Act	15.66
10	Ideal	Ideal	Ideal	Act	16.02	10	Knw	Knw	Duty	Duty	15.56
11	Act	Duty	Duty	Ideal	15.78	11	Ideal	Duty	Duty	Act	15.24
12	Ideal	Ideal	Duty	Duty	15.73	12	Duty	Act	Act	Knw	15.04
13	Duty	Duty	Duty	Knw	15.2	13	Ideal	Act	Act	Act	14.57
14	Ideal	Ideal	Duty	Act	14.48	14	Knw	Act	Duty	Duty	14.52
15	Ideal	Act	Duty	Act	14.37	15	Act	Ideal	Ideal	Ideal	14.27
16	Ideal	Ideal	Knw	Knw	14.16	16	Duty	Ideal	Ideal	Ideal	14.2
17	Duty	Duty	Act	Knw	13.74	17	Act	Knw	Knw	Knw	14.16
18	Ideal	Ideal	Knw	Duty	13.62	18	Ideal	Ideal	Knw	Act	14.08
19	Ideal	Ideal	Act	Act	13.35	19	Ideal	Knw	Knw	Act	14.06
20	Duty	Duty	Ideal	Knw	13.12	20	Duty	Knw	Knw	Knw	13.95
21	Act	Ideal	Act	Act	13.11	21	Act	Act	Act	Knw	13.83
22	Ideal	Ideal	Knw	Act	12.46	22	Ideal	Knw	Knw	Duty	13.77
23	Act	Act	Knw	Duty	12.44	23	Ideal	Ideal	Knw	Duty	13.77
24	Ideal	Knw	Knw	Knw	12.41	24	Duty	Duty	Duty	Ideal	13.48
25	Knw	Knw	Knw	Knw	11.71	25	Duty	Duty	Duty	Knw	12.48
26	Act	Duty	Ideal	Knw	11.67	26	Duty	Duty	Act	Act	9.184
27	Act	Act	Act	Knw	11.23	27	Act	Duty	Act	Act	8.729
28	Knw	Knw	Duty	Duty	11.1	28	Act	Duty	Duty	Duty	8.322
29	Ideal	Knw	Duty	Knw	11.01	29	Ideal	Ideal	Ideal	Ideal	7.341
30	Act	Ideal	Act	Knw	10.52	30	Act	Act	Act	Act	6.579
31	Act	Knw	Duty	Knw	9.946	31	Duty	Duty	Duty	Duty	5.728
32	Ideal	Knw	Act	Knw	9.891	32	Ideal	Ideal	Ideal	Knw	5.662
33	Knw	Knw	Duty	Knw	9.561	33	Knw	Knw	Knw	Knw	4.703
34	Act	Knw	Act	Knw	8.772	34	Ideal	Ideal	Knw	Knw	4.63
35	Knw	Knw	Knw	Act	8.468	35	Ideal	Knw	Knw	Knw	4.336

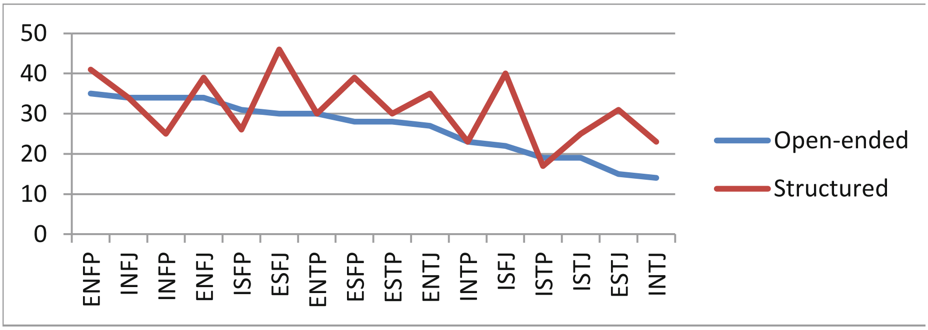

Fig. 6. Comparing the performance of personalities in open-ended and structured tasks

5.1 Temperament as a Factor in Effective Performance

To examine the impact of team composition in a more detail, we grouped agent-based simulation results with respect to temperament that is represented in Table 1, which is a generalization of the MBTI scheme [10]. There are then 35 possible combinations of teams according to temperament, and the team performances of these various combinations are shown for open-ended tasks, and for structured tasks in Table 7 – where "Duty" represents duty seekers, "Knw" represents knowledge seekers, "Act" represents action seekers and "Ideal" represents ideal seekers.

For structured tasks, there appeared to be an advantage in having homogeneity across duty seekers and ideal seekers (top two results). In contrast, homogeneous teams of action seekers and knowledge seekers did not perform well (ranked 9 and 25). In addition, combinations of duty seekers and action seekers tended to do well (ranked 3 and 4), while combinations of action seekers and ideal seekers were less successful. Although knowledge seekers did not generally perform well in this task category, their performance was relatively better when they teamed with ideal seekers. For example when a knowledge seeker teamed with three ideal seekers, it ranked fifth overall.

For open-ended tasks the best combination was two ideal seekers with two action seekers. In addition the combination of duty seekers and action seekers teamed with either knowledge seekers or ideal seekers did well. In general, heterogeneous teams had good performance for these tasks. Homogeneous teams were relatively less successful, and even the best homogeneous team (all ideal seekers) was only ranked 29th out of the 35 teams. Overall, the relative success of the combination of ideal seekers and action seekers was presumably due the fact that the team combined situational openness with active performance. Knowledge seekers fared poorly; but the combination of knowledge seekers with duty seekers performed better than the combination of ideal seekers with duty seekers, and the combination of knowledge seekers with action seekers did better than the combination of duty seekers and action seekers.

6 Conclusion

In this paper we have introduced our model for agent behaviour in a pervasive team-oriented game environment. Our agent-based simulations have demonstrated the effect of individual personalities with respect to a team's performance, where we have employed the Myers-Briggs Type Indicator (MBTI) to characterize individual player personality.

In addition, we have used our modelling framework to demonstrate how one can investigate the effect of various personality interactions on overall team performance with respect to four-person teams. Our agent-based simulations have demonstrated how some player combinations of player temperaments can enhance the overall efficiency of a team, while other combinations can prove to be detrimental. The demonstration of these effects, we believe, can prove to be useful both to designers of serious games and to policy makers in general: by employing this framework, designers and policy makers can examine the degree to which cooperative teamwork is a key influence in overall team performance.

In the future we intend to extend our investigations in connection with this agent-based gameplay framework in several ways. Up to now we have kept player personality separate from individual skill level, but future work will examine connections between personality traits and difficulty (for example, response to frustrations and recovery from setbacks), as well as the connection between personality traits and exploratory activity (a form of creativity). In addition, we will be examining how competitive teams or a given collective personality composition may alter their behaviour in response to the presence of competing teams of differing personality compositions. We have also so far considered personality to be essentially static, but in the future, we will also develop a dynamic player personality model that affords some shifts in attitude and social trust in response to activities during games.

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