A Believable Group in the Synthetic Mind

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Abstract

In recent years, virtual environments have evolved from single user and single agent, to multi-user and multi-agent. Furthermore, with the emergence of synthetic characters, collaborative virtual environments can now be populated with characters and users, all interacting, collaborating or competing between each other. However, the user's interaction with the synthetic characters is not always the best, and it is only positive if the characters are able to show a coherent and believable behaviour. Therefore, in scenarios where users and synthetic characters interact as a group, it is very important that the interactions follow a believable group dynamics. Focusing on this problem, we have developed a model that supports the dynamics of a group of synthetic characters, inspired by theories of group dynamics developed in human social psychological sciences. The dynamics is driven by a characterization of the different types of interactions that may occur in the group, which are differentiated in two main categories: the socio-emotional interactions and the task related interactions.

1 Introduction

The use of synthetic characters in interactive virtual environments can greatly improve the user interaction with the environment and lead to more believable and real simulated worlds. However this positive effect highly depends on the richness of the characters' actions and interactions, or, more concretely, on the characters' *believability*. A *believable* character according to Bates (1994) is a character that provides the illusion of life, and thus leads to the audience's suspension of disbelief.

In addition, results obtained by Reeves and Nass (1998) show that people interactions with computers are fundamentally social. These findings suggest the importance of social behaviour in the believability of synthetic characters, and have inspired and fostered the research on this topic. However, although the research has been conducted on many different issues, there is one that has been rarely addressed: the believability of synthetic characters when engaging in a group that collaboratively performs a task.

This group believability is crucial in collaborative scenarios that involve both human and synthetic participants, which are nowadays more common in particular in entertainment and education scenarios.

In this paper we present a model for the synthetic minds of the characters, inspired on theories of group dynamics developed in human social psychological sciences, that we believe to improve the users' interaction experience in groups of synthetic characters.

This paper is organised as follow. First we will discuss the motivation for this research showing some examples where it could be applied. Then we present an abstract architecture that supports the implementation of our model of synthetic group dynamics, which is followed by the description of the model. In the end we draw some conclusions.

2 The Motivation

With the emergence of synthetic characters, collaborative virtual environments can now be populated at the same time with characters and users, all interacting together. Examples of this can be found in many different scenarios, for example in computer games, more specifically Role Playing Games[1], such as "The Temple of Elemental Evil"(Troika, 2003) and the "Star Wars: Knights of the Old Republic"(Bioware, 2003), in virtual communities on the internet such

[1] A Role Playing Game (RPG) is a game in which each participant assumes the role of a character (such as an brave medieval knight or a futuristic spaceship captain) that can interact within the game's imaginary world and its characters. Characters usually form groups and act together in the search for a solution to the world quests.

as the Activeworlds (Activeworlds, 1997-2005), or in educational applications like the STEVE system (Rickel and Johnson, 1999).

Furthermore, these environments may potentially join the users and the synthetic characters in groups that together engage the resolution of collaborative tasks. However, the interacting capabilities of the synthetic characters in such cases usually fail to meet the user's social expectations and their suspension of disbelief (Bates, 1994), which consequently leads to lower levels of user's satisfaction with the interaction experience. Thus, to avoid this effect, usually the synthetic characters take a secondary role in the group interactions. For example, in Role Playing Games, where the social interactions take an important part of the game, usually the role of the autonomous characters is very restricted. Additionally, it is frequent that the players have some control over the characters, which reduces their autonomy. For example, in the "Star Wars: Knights of the Old Republic"(Bioware, 2003) game the player starts the adventure with one character, but as the game evolves other characters join the player's quest and s/he will end up controlling simultaneously an entire party of several characters. This fact increases the distance between the player and her/his character and decreases the role play of the game and consequently the user's satisfaction. For this reason, and in order to achieve a better level of role playing, Role Playing Games are often played by several users each one controlling a single character and the autonomous characters are limited to the role of servants or companions that follow their masters and do not actively participate in the group. Therefore, if synthetic characters can interact and collaborate in a natural way within a group of human players, thus, following a believable group dynamics, they could participate more actively in the group and take more central roles in the game. Furthermore, in the absence of other human players, these synthetic characters could bring the same levels of role play to the game and make it as enjoyable as if there are only humans involved.

Moreover, in education and training the believability of the group interactions may enhance the applications that train team work, such as STEVE (Rickel and Johnson, 1999). The team training can be enhanced by additionally including some social training to endow the learners with the ability to manage the group social relationships as well as the action cooperation procedures. However, to achieve this it is crucial that the synthetic participants behave in a believable way towards the group and its members.

The same ideas can be applied to children's education. Researchers have found that learning in group may foster the knowledge building ability of the learners (Stright and Supplee, 2002). For example, Aebli (1951) supported on Piaget's theory of cognitive development (Piaget, 1955) stated that learning how to behave in group is fundamental to early children development, since working and discussing with others requires the children to take different points of view and see the other's perspective. This effort help children to get a more flexible and logical reasoning moving their thought from egocentric to operational. This process of children development can be supported by computer software that simulates believable group interactions.

This paper presents our approach to increase the believability of the group interactions between users and synthetic characters. We believe that the synthetic characters' group behaviour should resemble as much as possible the group behaviour the users found in their real world group interactions. Therefore, we sought inspiration on theories of group dynamics developed on human social psychological sciences, to design a model for mind of these synthetic characters.

3 The Architecture

To support the implementation of the model for the believable group dynamics on the synthetic characters (which are implements as autonomous agents), we propose an abstract architecture for their minds. The architecture, as shown in figure 1, is composed by four main modules that are responsible for the agent's perception, knowledge, behaviour and action. The information flows from the agent's sensors on the world to its perception module that consequently updates the knowledge base. Then, based on this knowledge the agent's behaviour module decides which actions are more suitable to follow the current goals and asks the action module to request the execution of the correspondent effectors on the world.

Furthermore, this architecture defines two different sub components on both the knowledge and the behaviour modules to handle respectively the concepts of group and task. Moreover, the architecture modules will now be described in more detail:

1. **Perception:** the perception module is responsible for handling the incoming perceptions and with their information generate new knowledge for the knowledge module. Thus, it translates the perceptions into facts that represent the abstract entities, their properties, relations and ac-

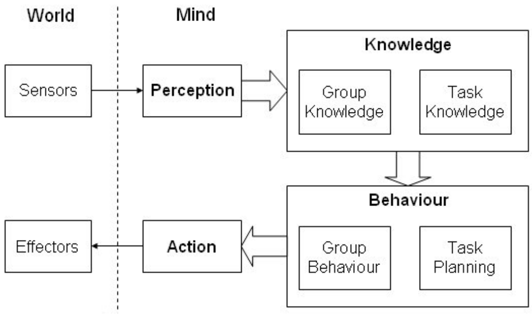

Figure 1: A mind architecture that supports the implementation of the model of group dynamics.

tions.

2. **Knowledge:** the knowledge module stores the model that the agent builds about the world. It contains facts that represent the agent's beliefs concerning itself and the other entities in the world. In particular it records a list with the actions performed by the other agents, that is useful for the determination of the group interaction categories. In addition, this module contains two specific components that handle the knowledge about the group and about the task.

   (a) *Group Knowledge:* this sub component infers, from the common knowledge stored in the knowledge module, information about the group: (1) it characterizes the individual members, for example in terms of their personality and abilities, (2) it assesses the group state and structure, by deducting the social relations between the group members, and (3) it classifies the members actions into categories of group interaction.

   (b) *Task Knowledge:* this sub component is responsible for the knowledge of the group tasks: (1) it stores information about the current, and past, tasks of the group and their correspondent goals, (2) it monitors the state of execution of each of these tasks, and (3) it defines a model for the tasks that determines for example, how each individual action affects the execution of the task.

3. **Behaviour:** this module is responsible for the agent's decision concerning its behaviour. It decides when to act and what action to take. These decisions are always based on the agent current beliefs that can be found on the knowledge module. In addition, the behaviour module contains two sub components; one responsible for the group behaviour and the other for the task execution.

   (a) *Group Behaviour:* this sub component decides, based on the group knowledge, how often should the agent perform and what are the pertinent situations when the agent should act. In addition, it decides what type of group interactions should the agent engage and what members should it address.

   (b) *Task Planning:* this sub component decides, based on the task model, the group current tasks and the knowledge inferred about the individual members, what is the best plan to achieve the group's goals. Then, from this plan, the agent derives its next action.

4. **Action:** the action module translates the action proposed by the behaviour module into specific executions of the agent's effectors in the world.

4 The Model for Group Believability

The proposed model (SGDModel - Synthetic Group Dynamics Model) is based in the principle that a character must be aware of the group and its members and should be able to build a proper social model of the group and reason with it. To build such a model we have relied on theories of group dynamics developed in human social psychological sciences, in particular Cartwright and Zander (1968), Bales (1950) and McGrath (1984).

In the model, we consider a *group* as a system composed by several agents, which engage in interaction processes that drive the dynamics of the system. Agents themselves, apart from their knowledge of the task and their individual goals, also contain a model the group, which is characterized at four different levels:

1. **the individual level** that defines the individual characteristics of each group member (thus, what each agent knows about the individual characteristics of the others);

2. **the group level** that defines the group and its underlying structure;

3. **the interactions level** that defines the different classes of interactions and their dynamics;

4. **the context level** that defines the environment and the nature of the tasks that the group should perform.

4.1 The Individual Level

On the individual level each agent is modelled as an unique entity, and defined by the following predicate:

$$Agent(Name, Skills, Personality) \tag{4.1}$$

Where *Name* is an unique id of the agent, *Skills* represent the set of the abilities that the agent can use in the task resolution, and *Personality* defines the agent personality according to the Five Factor Model McCrae and Costa (1996). We have simplified the personality of our agents and have only considered two of the five factors proposed in the Five Factor Model: *extraversion* and *agreeableness*; that according to BalesActon (2004) are associated with the ideas of dominant initiative and socio-emotional orientation.

4.2 The Group Level

On the group level, the model considers a group and its underlying structure as well as the agents' attitude towards the group. A group is defined by the following predicate:

$$Group(Identity, Members, Structure) \tag{4.2}$$

The *Identity* defines a way to distinguish the group in the environment, thus allowing its members to recognize and refer to it. *Members* is the set of agents that belong to the group. These agents follow the definition presented in 4.1. The group *Structure* emerges from the members relations and can be defined at different dimensions. According to Jesuino Jesuno (2000) these dimensions are: (1) the structure of communication; (2) the structure of power; and (3) the structure of interpersonal attraction (sociometric structure Moreno (1934)). We have assumed that the structure of communication is simple (all agents communicate directly with each other) and therefore we will focus on the group structure only in two dimensions: the *structure of power* that emerges from the members' social influence relations, and the *sociometric structure* that emerges from the members' social attraction relations.

Furthermore, to define the group structure we must define the social relations between all the group members following these two definitions:

$$SocialInfluence(Source, Target, Value) \tag{4.3}$$

$$SocialAttraction(Source, Target, Value) \tag{4.4}$$

The social relations are directed from one agent, the *Source*, to another, the *Target*, and are assessed by a *Value* which can be positive, zero or negative. For example *SocialAttraction(A,B,50)* denotes that agent A has a positive social attraction for (e.g. likes) agent B.

In addition to the relations that agents build with each other, agents also build a relation with every group they belong to. This relation captures the member's attitude towards the group and supports the notion of membership. Thus, for each group that an agent belongs to, we define one membership predicate according to the following definition:

$$Membership(Agent, Group, Motivation, Attraction, Position) \tag{4.5}$$

Agent and *Group* are the identifiers of the agent and the group respectively. The *Motivation* defines the level of engagement of the agent in the group's interactions and tasks. The *Attraction* assesses the level of attachment of the agent to the group. Agents with high levels of *Attraction* are very tied to the group while agents with low levels of *Attraction* are not very attached and thus can easily leave the group. The *Position* reflects the strength of the agent actions in the group, which depends on the social relations that the agent builds with the other members of the group and how skillful it is in the group. E.g. actions performed by agents that have more social influence over the others, or that the others like more, have stronger effects on the group. The group *Position* is computed using the following formula:

$$\begin{aligned} &\forall Group(G) \wedge A \in Members(G): \\ &Position(A,G) = SkillLevel(A,G) + \\ &\sum_{m \in Members(G)}^{m} SocAttraction(m,A) \\ &+ \sum_{m \in Members(G)}^{m} SocInfluence(A,m) \end{aligned} \tag{4.6}$$

4.3 The Interactions Level

At the interactions level, the model categorizes the possible interactions in the group and defines their dynamics. The term interaction is related to the execution of actions, that is, one interaction occurs when agents execute actions that can be perceived and evaluated by others. An interaction is defined in the model as:

$$Interaction(Type, Performers, Targets, Supporters, Strength) \quad (4.7)$$

Where *Type* defines the category of the interaction; *Performers* is the set of agents that were responsible for the occurrence of the interaction; *Targets* is the set of agents that are influenced by the interaction; *Supporters* is the set of agents that support the interaction (e.g agree with it) but are not directly involved on its occurrence; and *Strength* defines the importance of the interaction to the group. The *Strength* is directly related with the position that the *Performers* and *Supporters* have in the group, which means that the better the positions of these agents in the group the stronger will be the interaction effects.

4.3.1 The Classification of the Interactions

The classification of an interaction depends on the interpretation of the agent that is observing the interaction, which means that the classification process is dependent on the agent's knowledge and its perception of the world events. E.g. the same action can be perceived to be positive to the group by one agent but negative in the view of another.

To support the classification of interactions we have defined a set of categories following the studies performed by Bales (1950) on his Interaction Process Analysis (IPA) system. Bales argued that members in a group are simultaneously handling two different kind of problems: those related with the group task and those related to the socio-emotional relations of its members. Based on this, in the model, the members interactions are divided in two major categories: the *instrumental interactions* (related with the task) and the *socio-emotional interactions*. Furthermore, the interactions can be classified as positive, if they convey positive reactions on the others, or negative, if they convey negative reactions.

Socio-emotional interactions fall into four categories:

1. **Agree [positive]:** this class of interactions show the support and agreement of one agent towards one of the interactions of another agent consequently raising the importance of that interaction in the group.

2. **Encourage [positive]:** this class of interactions represent one agent's efforts to encourage another agent and facilitate its social condition.

3. **Disagree [negative]:** this class of interactions show disagreement of one agent towards one of the interactions of another agent, consequently decreasing the importance of that interaction in the group.

4. **Discourage [negative]:** this class of interactions represent one agent's hostility towards another agent and its efforts to discourage it.

In addition we defined four categories of instrumental interactions:

1. **Facilitate Problem [positive]:** this class of interactions represent the interactions made by one agent that solves one of the group problems or ease its resolution.

2. **Obstruct Problem [negative]:** this class of interactions represent the interactions made by one agent that complicates one of the group problems or render its resolution impossible.

3. **Gain Competence [positive]:** this class of interactions make one agent more capable of solving one problem. This includes for example the learning of new capabilities, or the acquisition of information and resources.

4. **Loose Competence [negative]:** this class of interactions make one agent less capable of solving one problem. For example by forgetting information or loosing the control of resources.

4.3.2 The Dynamics of the Interactions

Interactions create dynamics in the group. Such dynamics is modelled through a set of rules, supported by the theories of social power by French and Raven (1968) and Heider's balance theory (Heider, 1958). Such rules define, on one hand, how the agent's and the group's state influence the occurrence of each kind of interaction, and on the other, how the occurrence of each type of interaction influences the agent's and group's state.

In general the frequency of the interactions depends on the agent's *motivation*, *group position* and *personality* (Shaw, 1981) (McGrath, 1984) (Acton, 2004). Thus, highly motivated agents engage in more interactions, as well as agents with a good group position or high extraversion. On the other hand, agents not motivated, with a low position in the group, or with low levels of extraversion will engage in few interactions or even not interact at all. These elements of the model are captured by the rule synthesized in the following equation:

$$\forall Group(G) \wedge Interaction(I) \wedge A \in Members(G) : \\ Extravert(A) \wedge GroupPosition(A,G) \wedge \\ Motivation(A,G) \vdash Starts(A,I,G) \tag{4.8}$$

The agent's personality also defines some of the agent tendencies for the social emotional interactions (Acton, 2004). Agents with high levels of *agreeableness* will engage more frequently in positive socio-emotional interactions while agents with low *agreeableness* will favour the negative socio-emotional interactions. This leads us to the second rule:

$$\forall Group(G) \wedge SocEmotInt(I) \wedge A \in Members(G) : \\ High(Agreeable(A)) \vdash Starts(A,I,G) \wedge Positive(I) \\ Low(Agreeable(A)) \vdash Starts(A,I,G) \wedge Negative(I) \tag{4.9}$$

Furthermore, the agent's skills influence the occurrence of the instrumental interactions. Thus, more skilful agents will engage in more instrumental interactions than non skilful agents (McGrath, 1984). This fact is expressed in the following rule:

$$\forall Group(G) \wedge InstrInt(I) \wedge A \in Members(G) : \\ Skilful(A) \vdash Starts(A,I,G) \tag{4.10}$$

Moreover, agents with higher *position* in the group are usually the targets of more positive socio-emotional interactions while the agents with lower *position* are the targets of more negative socio-emotional interactions (McGrath, 1984)[2]. In addition, when one agent is considering to engage in a socio-emotional interaction its social relations with the target are very important. Members with higher social influence on the agent and/or members for which the agent has a positive social attraction will be more often targets of positive socio-emotional interactions, otherwise they will be more often targets of negative socio-emotional interactions. The next two rules express these tendencies:

$$\forall Group(G) \wedge SocEmotInt(I) \wedge \\ A,B \in Members(G) : \\ High(Position(B,G)) \wedge \\ High(SocAttraction(A,B)) \wedge \\ High(SocInfluence(B,A)) \\ \vdash Starts(A,I,B,G) \wedge Positive(I) \tag{4.11}$$

$$Low(Position(B,G)) \wedge Low(SocAttraction(A,B)) \wedge \\ Low(SocInfluence(B,A)) \\ \vdash Starts(A,I,B,G) \wedge Negative(I) \tag{4.12}$$

On the other hand, the group interactions also affect the group state. For example, the *positive instrumental interactions* will increase its performers *social influence* on the members of group as well as its own *motivation*. Which means that any member that demonstrates expertise and solves one of the group's problems or obtains resources that are useful to its resolution will gain influence over the others (French and Raven, 1968). On the other hand members that obstruct the problem or loose competence will loose influence on the group and become less motivated [3]. These rules are resumed as follows:

$$\forall Group(G) \wedge InstrInt(I) \wedge A,B \in Members(G) : \\ Starts(A,I,B,G) \wedge Positive(I) \wedge \\ Motivation(A,G,m_1) \wedge SocInfluence(A,B,si_1) \\ \vdash Motivation(A,G,m_2 : (m_2 > m_1)) \wedge \\ SocInfluence(A,B,si_2 : (si_2 > si_1)) \tag{4.13}$$

$$Starts(A,I,B,G) \wedge Negative(I) \wedge \\ Motivation(A,G,m_1) \wedge SocInfluence(A,B,si_1) \\ \vdash Motivation(A,G,m_2 : (m_2 < m_1)) \wedge \\ SocInfluence(A,B,si_2 : (si_2 < si_1)) \tag{4.14}$$

Socio-emotional interactions by its turn are associated with changes in the *social attraction* relations. One agent changes its attraction for another agent positively if it is target of positive socio-emotional interactions by that agent and negatively otherwise. The encourage interaction has the additional effect to increase the target's *motivation* in the group. The next

[2]Note that an agent has an high group position if it has high influence over the others and/or if the others have an high social attraction for it.

[3]It can be argued that certain people with certain personality traits become more motivated when they fail to achieve a task, however this is not the most common behaviour, and therefore we did not model it.

equations resume these rules:

$$\begin{aligned} &\forall Group(G) \wedge SocEmotInt(I) \wedge \\ &A, B \in Members(G): \\ &Starts(A, I, B, G) \wedge Positive(I) \wedge \\ &SocAttraction(B, A, sa_1) \\ &\vdash SocAttraction(B, A, sa_2 : (sa_2 > sa_1)) \quad (4.15) \\ &Starts(A, I, B, G) \wedge Negative(I) \wedge \\ &SocAttraction(B, A, sa_1) \\ &\vdash SocAttraction(B, A, sa_2 : (sa_2 < sa_1)) \quad (4.16) \\ &Starts(A, I, B, G) \wedge Encourage(I) \wedge \\ &Motivation(A, G, m_1) \\ &\vdash Motivation(A, G, m_2 : (m_2 > m_1)) \quad (4.17) \\ &Starts(A, I, B, G) \wedge Discourage(I) \wedge \\ &Motivation(A, G, m_1) \\ &\vdash Motivation(A, G, m_2 : (m_2 < m_1)) \quad (4.18) \end{aligned}$$

Agents also react to socio-emotional interactions when they are not explicitly the targets of the interaction. Following Heider's balance theory (Heider, 1958), if one agent observes a positive socio-emotional interaction on an agent that it feels positively attracted to then its attraction for the performer of the interaction will increase. Similar reactions occur in the case of negative socio-emotional interactions. If in the latter example the agent performed a negative socio-emotional interaction then the observer's attraction for the performer would decrease. These rules are shown in the following equations:

$$\begin{aligned} &\forall Group(G) \wedge SocEmotInt(I) \wedge \\ &A, B, C \in Members(G): \\ &Starts(A, I, B, G) \wedge Positive(I) \wedge \\ &SocAttraction(C, A, sa_1) \wedge \\ &High(SocAttraction(C, B)) \\ &\vdash SocAttraction(C, A, sa_2 : (sa_2 > sa_1)) \quad (4.19) \\ &Starts(A, I, B, G) \wedge Negative(I) \wedge \\ &SocAttraction(C, A, sa_1) \wedge \\ &High(SocAttraction(C, B)) \\ &\vdash SocAttraction(C, A, sa_2 : (sa_2 < sa_1)) \quad (4.20) \end{aligned}$$

The intensity of the interactions' effects described on the previous rules depends directly on the strength of the interaction in the group. For example encourage interactions performed by members with a better position in the group will increment more the target's motivation. By its turn the interactions' strength depends on the agent's group position, thus, we can say that the group position is a key factor and the main driver for the dynamics of the group. Therefore, to perform well in the group, an agent should take care of its social relations with the other members in the group, since these social relations support its position in the group.

4.4 The Context Level

Finally, in the context level is defined the environment where the agents perform and the nature of the group's tasks. One of these important definitions is the type of actions that the agents may perform and their potential classification as interactions according to this model. The context can also define some social norms that may drive the interaction process. However, our model does not define any particular mechanism for the creation of social norms or the definition of group tasks.

5 Conclusions

In this paper we have argued that group believability of synthetic characters is important, when among the group, we have characters and users interacting with each other.

To achieve such group believability, we have proposed a model inspired by theories of group dynamics developed in human social psychological sciences. The dynamics is driven by a characterization of the different types of interactions that may occur in the group. This characterization addresses socio-emotional interactions as well as task related interactions.

In addition we have presented an abstract architecture for the mind of the characters that supports the implementation of the proposed model in their behaviour.

Acknowledgements

This work has been developed with the support of a scholarship (PRAXIS XXI/BD/21658/99) granted by the *Fundação para a Ciência e a Tecnologia*.

References

Activeworlds. The activeworlds website. *(online) http://www.activeworlds.com*, 1997-2005.

Scott Acton. Great ideas in personality. *(online) http://galton.psych.nwu.edu/bigfive.html*, 2004.

H. Aebli. *A Didactics founded on the psychology of Jean Piaget*. Kapelusz, 1951.

Robert Freed Bales. *Interaction Process Analysis*. The University of Chicago Press, Chicago, 1950.

Josheph Bates. The role of emotions in believable characters. *Communications of the ACM*, 37(7): 122–125, 1994.

Bioware. Star wars: Knights of the old republic. *(online) http://www.lucasarts.com/products/swkotor/*, 2003.

Dorwin Cartwright and Alvin Zander. *Group Dynamics: Research and Theory*. Harper and Row, New York, 1968.

John R. P. French and Bertram H. Raven. *Group Dynamics: Research and Theory*, chapter Bases of Social Power. Harper and Row, New York, 1968.

Fritz Heider. *The Psychology of Interpersonal Relations*. Wiley, New York, 1958.

Jorge Correia Jesuno. *Psicologia Social*, chapter Estrutura e processos de grupo: interaccoes e factores de eficacia. Fundacao Calouste Gulbenkian, 2000.

R. McCrae and P. Costa. *The five factor model of personality: Theoretical perspectives*, chapter Toward a new generation of personality theories: Theoretical contexts for the five factor model, pages 51–87. Guilford, New York, 1996.

Joseph E. McGrath. *Groups: Interaction and Performance*. Prentice Hall, Englewood Cliffs, New Jersey, 1984.

J. L. Moreno. *Who Shall Survive?* Nervous and Mental Disease Publishing Co., Washington D.C., 1934.

Jean Piaget. *The Construction of Reality in the Child*. MIT Press, 1955.

Bryon Reeves and Clifford Nass. *The Media Equation. How People Treat Computers, Television, and New Media Like Real People and Places*. Cambridge University Press, 1998.

Jeff Rickel and W. Lewis Johnson. Virtual humans for team training in virtual reality. In *Proceedings of the Ninth International Conference on AI in Education*, pages 578–585, 1999.

M. E. Shaw. *Group Dynamics: the Psychology of Small Group Behaviour*. McGraw-Hill, New York, 1981.

A. D. Stright and L. H. Supplee. Children's self-regulatory behaviors during teacher-directed, seat-work, and small-group instructional contexts. *Journal of Educational Research*, 95(4):235–244, 2002.

Troika. The temple of elemental evil. *(online) http://www.atari.com/toee/*, 2003.