Maintaining the Identity of Dynamically Embodied Agents

Alan Martin[1], Gregory M. P. O'Hare[1], Brian R. Duffy[2], Bianca Schön[1], and John F. Bradley[1]

[1] University College Dublin, Belfield, Dublin 4, Ireland
[2] Institut Eurécom, Sophia-Antipolis, France
{alan.martin, gregory.ohare, bianca.schoen, john.bradley}@ucd.ie
Brian.Duffy@eurecom.fr
http://chameleon.ucd.ie

Abstract. Virtual agents are traditionally constrained in their embodiment, as they are restricted to one form of body. We propose allowing them to change their embodiment in order to expand their capabilities. This presents users with a number of difficulties in maintaining the identity of the agents, but these can be overcome by using identity cues, certain features that remain constant across embodiment forms. This paper outlines an experiment that examines these identity cues, and shows that they can be used to help address this identity problem.

1 Introduction

Over the last number of years, extensive research has been carried out into the area of autonomous agents. These are software entities characterised by the attributes of autonomy, social ability, reactivity and pro-activity [1]. A number of features of agent technologies, including their autonomy, their ability to reason based upon limited knowledge and their ability to react to changes in the environment, make them suitable for use within virtual environments. Agents within virtual environments are referred to as *virtual agents*, where they normally control a graphical representation of themselves, called an *avatar*.

A number of different systems have sought to incorporate agents within virtual environments. These include the MAVE system, developed by Cobel, Harbison & Cook [2, 3], which seeks to place virtual agents within a web based VRML environment. Also, André and Rist have developed MIAU, a system that animates characters based upon either a behaviour component or a response to user interaction [4].

Traditionally an agent's avatar is constrained to a single form, including in the above systems. This has a number of limitations on the agent's capabilities, as the capabilities are defined by the form of the avatar. We advocate a different

[1] This paper appears in the Proceedings of the Fifth International Working Conference on Intelligent Virtual Agents - IVA 2005, Kos, Greece, September 2005. It can be downloaded from http://chameleon.ucd.ie

system, the agent is capable of mutating its embodiment in order to expand upon its capabilities. The agent's embodiment is then dynamic and can change in order to take advantage of different capability sets. However, this freedom does present a number of difficulties, particularly in relation to the agent's identity.

We define an agent's *identity* to be that which causes the agent to remain the same within the mind of the user. Maintenance of identity, despite the ability to change form, is vital, as the user must be capable of identifying the agent being dealt with, even if its appearance has changed significantly. In order to achieve this, we propose a system whereby agents are equipped with a number of *identity cues*. These are distinctive features that are common to all of the possible forms of the agent.

In this paper we examine the influence of these cues in maintaining the agent's identity. Section 2 introduces Agent Chameleons, a system for the provision of expanded capabilities through migration and mutation. Section 3 discusses embodiment and suggests how the embodiment could be capable of change. Section 4 looks at identity and how it can be maintained with dynamic embodiment. Section 5 then explains the experimental methodology used to examine this notion, with the results detailed in Sect. 6.

2 Agent Chameleons

This research forms part of the the Agent Chameleons project [5–8], in which we endeavour to create the next generation of virtual agents, autonomic entities that can seamlessly migrate, mutate and evolve between and within virtual information spaces. The Agent Chameleon can be seen as a digital *spirit*, capable of occupying a variety of different platforms, such as a physical entity (a robot), a virtual environment, or a mobile device such as a PDA.

The key concepts of migration and mutation underpin these agents, allowing them to react to environmental change. Agent Chameleons are capable of migrating to a wide variety of devices and information spaces as required, in order to utilise the features and capabilities of each. For instance an agent could migrate to a real world robot in order to achieve a physical manifestation and influence physical reality, to a PDA in order to travel with the user, or to a virtual environment in order to improve its abilities for interacting with the user.

Additionally, the agents are capable of mutating their form. This is particulary relevant within virtual environments, where the form of an agent is not constrained as it is in the real world, and is capable of changing to suit the task at hand.

We propose a system in which such agents are controlled by a *Belief-Desire-Intention* (BDI) architecture [9–11]. Specifically, the agents' deliberative mechanism is based upon Agent Factory [12–15]. Agent Factory provides a cohesive framework for the development and deployment of agent-oriented applications, delivering extensive support for the creation of BDI agents. The Agent Factory Run-Time Environment supports the deployment of agent-oriented applications across a large number of platforms. Agent Chameleons expands upon this by providing these agents with the ability to operate within a number of platforms and devices, and to migrate between them. The system also allows the agents to mutate their form when located within virtual environments.

It should be noted that a number of other virtual agent systems exist that also embrace BDI based reasoning. These include the VITAL system developed by Anastassakis et al. [16], systems developed by Torres et al. [17] and Huang et al. [18], the Avatar Arena system developed by Rist el al. [19] and PsychSim, a system for the control of synthetic characters used to educate children in how to recognise and deal with bullying [20].

3 Embodiment

The relationship between the mind and the body has been a psychological and philosophical problem for many years. For example, Descartes [21] argued that the mind and the body are distinct entities and can interact independently of one another. Within the Artificial Intelligence (AI) community, this question has also arisen. Popularised by Brooks [22], the predominant view is that while the mind and body can be seen as different components, they are not necessarily separable. The embodiment of the intelligent system is crucial, as it is through this embodiment that a system interacts with the world.

Within virtual environments an agent's (or a user's) embodiment has been defined as the provision of an appropriate body image for the representation of that agent to other agents and users, as well as to itself [23]. Normally, a virtual agent is embodied through an *avatar*, a graphical representation of the agent within the virtual environment. The use of embodiment within a virtual environments is crucial for the user to develop a sense of presence within the world. *Presence* refers to the subjective experience of being in one place or environment, even when one is physically situated in another [24]. Gerhard et al. state that the use of avatars to embody users within multi-user virtual environments encourages a sense of presence in those users [25]. It also helps users to understand the persona of the other users, and facilitates social encounters with those users. Gerhard et al. go on to state the the form of the avatar has an influence over the level of presence felt. They carry out experiments comparing user reactions to different types of avatars, concluding that realistic or cartoon-like avatars are better at inducing presence than abstract shapes.

Within Agent Chameleons, agents are not constrained to one particular environment. They are capable of *migration*, moving between various different platforms, such as a robot, a mobile device such as a PDA, or a virtual environment. Within all of these environments the agents are considered to be embodied. We define the *embodiment* of the Agent Chameleon to be its strong provision of environmental context, both individual and social. The agents have an embodiment within all environments, provided by the robot that they are controlling, or their representation within the virtual world. Within virtual environments, this embodiment is achieved by the provision of an avatar for the agent.

We define a *body-form* as a body that an agent can choose to adopt. Body-forms include the form of any robots that the agents can occupy, as well as the agent's choices of representation within a virtual environment, on a desktop or on a mobile device. Agents have traditionally been confined to a single form of avatar, a single body-form. This research proposes a contrasting approach, our vision is of a system whereby an agent can mutate between various different body-forms, depending upon its task. The choice of body-form limits the agent's capabilities as each has its own associated sets of capabilities. For example, the body-form of a robot is equipped with that robot's sensory and motor capabilities.

As the body-form is limited by the abilities provided by the environment that the agent is occupying, it must be provided by that environment. Within virtual environments, Agent Chameleons are provided with a library of different body-forms that they can adopt. Each of these body-forms also presents its own set of capabilities to the agent. For instance, a representation as a face may allow an agent to express certain facial expressions whereas a representation as a car will not. The ability to change body-form, therefore, enables the agent to expand its capability set by selecting the most appropriate body-form to its task.

In this way the concept of body-form is distinct from the traditional notion of a *body*, the physical instantiation of an individual. As agents are capable of switching between body-forms, rather than a fixed one-mind-one-body relationship the agent has a one-mind-many-body-forms one, and can decide which of the body-forms is most suitable to its task. We refer this ability to change embodiments as *dynamic embodiment*, and to the act of changing body-form as *mutation*. More details on the architecture that supports dynamic embodiment can be found in [8].

4 Identity

Identity is not a simple concept, and indeed the definition of identity, as it is used in both common speech and academic research, has expanded and changed over the years. Fearon, in an examination of this changing definition of identity, claims that it is currently seen as being either

> "(a) a social category, defined by membership rules and (alleged) characteristics attributes or expected behaviours, or (b) socially distinguishing features that a person takes a special pride in or views as unchangeable but socially consequential (or (a) and (b) at once)." [26]

One important point to realise is that identity is primarily a social concept. As de Levita [27] noted, we present identity to others and have their identity presented to us. The question that defines identity is not, therefore, "Who am I?" but "Who am I in the eyes of others?".

With the ability to change the body-form, the issue of identity becomes important. If the agent can change its form, how can the notion of that agent be maintained? This maintenance of identity is vital if the agent is to operate

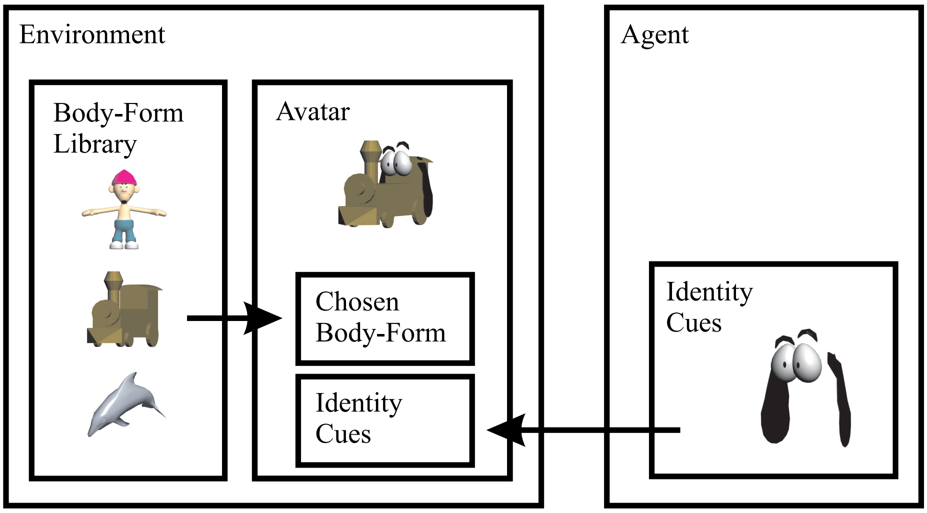

Fig. 1. The relationship between body-form and identity

successfully. Users must know who an agent is, regardless of its adopted body-form, if they are to develop a relationship with an agent and use it effectively. In order to achieve this, some understanding of the how humans perceive such identity is crucial.

We define an agent's *identity* to be that which causes an agent to remain the same within the mind of the user. It is what remains constant for the agent, regardless of its chosen body-form. It should be noted that the identity of the agent is primarily a perception of the user. This identity must be preserved across all body-forms that the agent can choose to adopt. In order to achieve this an agent has a number of features, called its *identity cues*, that remain constant across all body-forms, whenever possible. These identity cues help form the identity of the agent for the user.

The relationship between the the identity and the embodiment is outlined in Fig. 1. The body-form is a feature of the environment, as the environment defines the types of body-forms that are possible. On the other hand, identity and identity cues are features of the agent. Each agent has their own unique set of identity cues. When an agent is located within a virtual environment, the combination of its chosen body-form and identity cues is called the agent's *avatar*. The avatar is the agent's embodiment within the virtual world.

There are a number of different factors that can be used as identity cues, including visual factors such as the colour scheme, markings on the body, or particular features such as a specific style of eyes. Other possible identity cues include the type of character that the body-form represents (human, dog, insect) and non-visual factors such as the tone of voice used or the behaviour of the agent. The sense of identity applies not only to virtual environments, but to

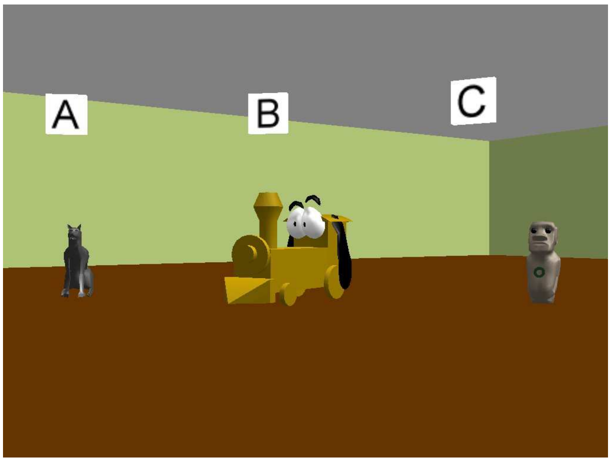

Fig. 2. Screen shot of the experimental environment.

other platforms that the agents can occupy; other platforms such as robots or PDA's should attempt to use the same identity cues.

Despite the importance of understanding what underpins identity perception, the question of how a dynamic embodiment affects how one identifies an individual has, so far, remained unaddressed. In order to attempt to rectify this, we carried out an experiment that looks into the influence of identity cues on the identity of a dynamically embodied agent.

5 Experimental Method

To investigate how identity cues can affect the users perception of a virtual agent's identity, and to look at which identity cues are more suitable, we devised a laboratory experiment. A random sample of volunteers were placed within a virtual environment and shown a virtual character. They were able to move around within the world and examine the character. This character was then replaced by three new characters, each with a different level of similarity to the original character. An example of this experimental setup is shown in Fig. 2. Participants were asked to rate "the degree you feel that each of these characters would be recognisable as the original character", giving each a score between 0 and 7. This was repeated a number of times within the experiment.

As this experiment is a preliminary investigation it was limited to characters located within a virtual environment. Additionally, the identity cues were limited to visual factors. A number of these cues were examined, specifically when:

- characters share a common feature, such as a hat or glasses.
- characters share a common colour scheme.
- characters share a common set of markings.

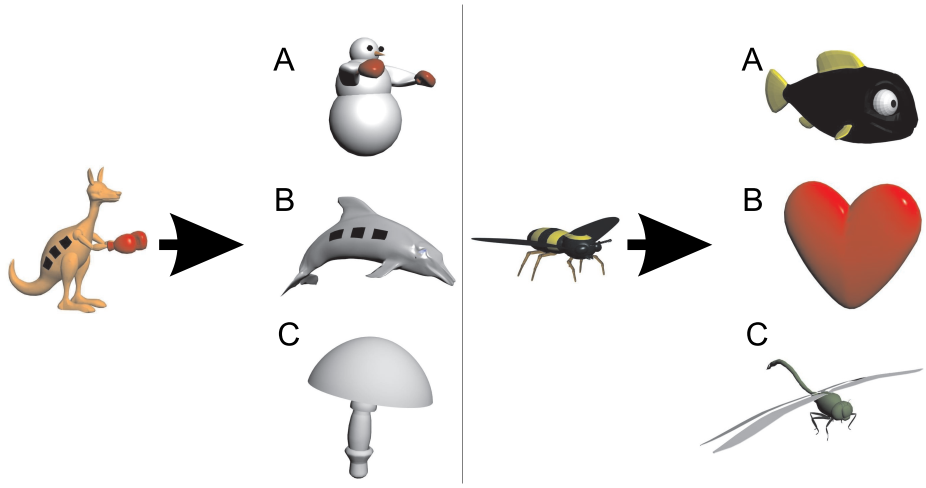

Fig. 3. Two sets of sample characters from the experiment.

– characters are of the same class of objects, for example characters are both human, or are both dogs.

While this is not an exhaustive set of the possible identity cues, it is adequate for this initial investigation.

For each set of characters in the experiment, each of the three characters shared only one identity cue with the original character. Additionally there were a number of characters that had no similarity to the original character that were used as controls. The test was carried out seven times for each participant, in a prescribed order. Each identity cue was repeated an identical number of times throughout these tests. Two examples of the character combinations are shown in Fig. 3. In the first (the kangaroo) where A has a common feature (i.e. boxing gloves), B has the same markings and C is a control. In the second (the wasp) A maintains colour, B is a control and C is the same class of character.

Participants were also asked some demographic questions, such as their age and gender, as well as being asked to rate their familiarity with both technology in general and computer games in particular.

6 Results

The experiment was carried out with a random sample of 31 individuals, 13 males and 18 females, aged between 8 and 50, with an average age of 23. The majority of participants were third-level students. The average score, out of 7, for the question of "receptiveness to technology" was 4.90, and the average score, again out of 7, for the question of "familiarity to computer games" was 3.83.

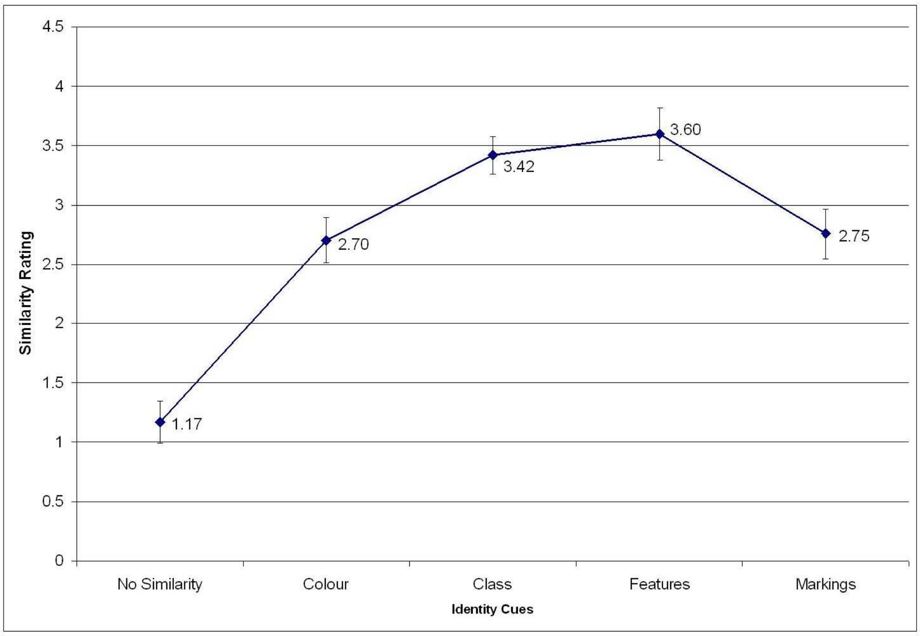

Fig. 4. The mean similarity score for each of the identity cues, with standard error indicated.

Analysis of the results suggest that the mean similarity score, for each of the identity cues, is as shown in Fig. 4. In order to ascertain that this represents a statistically valid difference between the different identity cues, an Analysis of Variance (ANOVA) was employed. The ANOVA is a standard method of identifying a statistically significant difference between means. A one-way ANOVA (repeated measures) was carried out on the main independent variable, the similarity score. The results, as shown in Table 1, reveal a significant difference between conditions ($F(4, 84) = 38.97; p < 0.001; MSE = 0.45$). Post-hoc analysis suggested that, with a significance level of $p < 0.001$, the four different identity cues were significantly different from the control case. Thus we can claim that the inclusion of identity cues affects the user's perception of the character's identity. Additionally, with a significance level of $p < 0.05$, the use of common features is significantly better than the use of colours and of common markings.

A few observations need to be made about these results. Considering the results for colour, the choice of colour used clearly has an influence. When the colours used were black and yellow (the wasp's colours, as is Fig. 3) a much higher rating was observed, with a mean score of 3.68, on the other hand when a less vivid green and blue combination was used, the rating was much lower, having a mean score of only 0.97, below that of the control characters.

Table 1. ANOVA Summary Table

Source	df	SS	MS	F	p-value
Identity Cues	4	69.93	17.48	38.97	0.00
Error	84	37.68	0.45		
Total	88	107.61			

There are a number of possible reason why this is the case. Research into human colour perception suggests that colour preference is learned rather than innate, and is influenced by a number of factors such as age, gender and culture. Studies also suggest that colour preference varies depending upon the object being coloured, with participants more open to colour variation in objects that can normally be seen in a variety of colours [28, 29]. Despite these complications, we argue that colour can still be an powerful identity cue, provided an appropriate colour scheme is chosen.

The maximum mean score for the identity cues is approximately 3.5, out of a maximum score of 7. While this is significantly better than the control cases, it is possible that this can be improved upon using a combination of identity cues. This experiment was, by design, limited to purely visual identity cues; one would imagine that the inclusion of non-visual cues, such as the auditory factors or behavioural consistency, will also have an affect. The use of these non-visual will also become important when identity must be maintained within non-virtual environments such as robots and PDA's, as visual cues are then difficult to maintain.

When the results were further analysed in relation to the gender of the participants, their level of technological familiarity and their level of games playing, no statistically significant differences were discovered. Despite this females have a consistently lower mean than males, as graphed in Fig. 5. This is consistent with findings into gender differences in visuo-spatial reasoning [30]. There still remains a number of factors that this experiment was unable to examine. For example, will a child present different results than an adult? Clearly a number of further experiments must be carried out in order to evaluate some of these factors.

7 Conclusions and Future Work

When virtual agents are equipped with dynamic embodiment, that is the ability to mutate their form, they are afforded the ability to take advantage of an expanded set of capabilities. However, this presents problems with the agent's identity, specifically how this can be maintained in the mind of the user.

Maintaining visual identity cues that transcend such avatar transmogrification is of paramount importance. This paper has explored this very issue and has formulated and conducted experiments that offer an understanding of visual enablers for the maintenance of agent identity. From the statistical analysis of

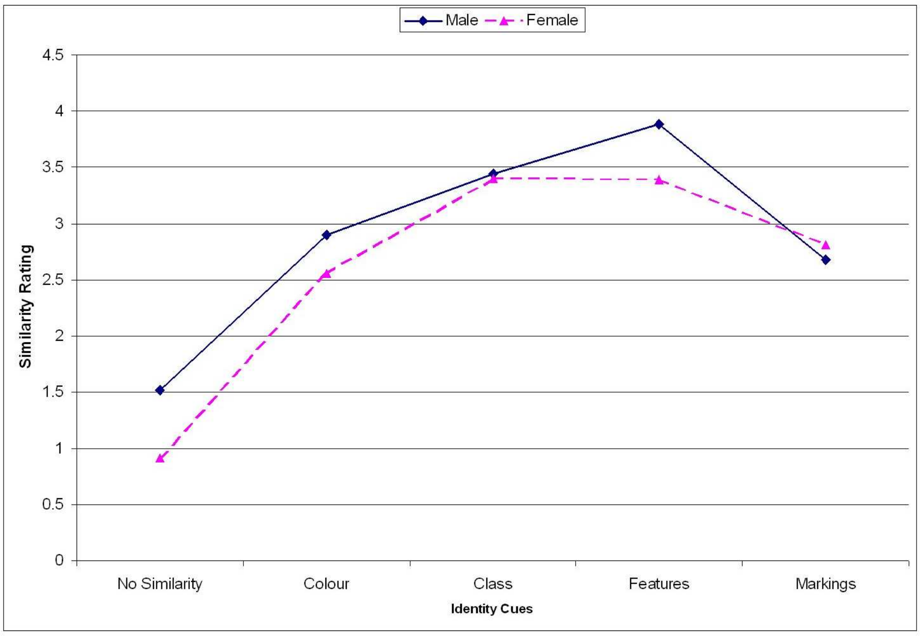

Fig. 5. The mean similarity score for males and females.

our experimental data, it can be concluded that the use of identity cues does indeed provide a valid method of maintaining an agent's identity when its embodiment is dynamic. Furthermore, it has been shown that the use of common features produces a higher level of identity than the use of common colours and markings. The Agent Chameleons must be equipped with these identity cues in order to aid the user in their identification of the agent when it mutates within the virtual environment and when it migrates from the virtual to the physical, such as to a robot or a PDA.

This work raises a number of questions that are yet to be answered. These include how other identity cues affect the result. The effect of behaviour and other non-visual cues, such as auditory cues, and the combination of identity cues also needs to be examined. Furthermore, questions are raised regarding the choice of colours that can be used for an identity cue, specifically what choices are appropriate and which are not. More experiments must be carried out in order to answer these questions.

Acknowledgements

The work undertaken as part of the Agent Chameleons project, a collaborative project between the Department of Computer Science, University College Dublin (UCD) and Media Lab Europe (MLE), Dublin. We gratefully acknowledge the financial support of the Higher Education Authority (HEA) Ireland and the Irish Research Council for Science, Engineering and Technology: funded by the National Development Plan. Gregory O'Hare gratefully acknowledges the support of Science Foundation Ireland under Grant No. 03/IN.3/1361.

References

1. Wooldridge, M., Jennings, N.R.: Intelligent agents: Theory and practice. Knowledge Engineering Review **10** (1994)
2. Cobel, J., Cook, D.J.: Virtual environments: An agent-based approach. In: Proceedings of the AAAI Spring Symposium on Agents with Adjustable Autonomy. (1999)
3. Cobel, J., Harbison, K.: MAVE: A multi-agent architecture for virtual environments. In: Proceedings of the Eleventh International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems. (1998) 577–583
4. Rist, T., André, E., Baldes, S.: A flexible platform for building applications with life-like characters. In: Proceedings of the Eight International Conference on Intelligent User Interfaces - IUI 2003, Miami, Florida, USA (2003)
5. Duffy, B.R., O'Hare, G.M.P., Martin, A.N., Bradley, J.F., Schön, B.: Agent chameleons: Agent minds and bodies. In: Proceedings of the Sixteenth International Conference on Computer Animation and Social Agents - CASA 2003, New Jersey, USA (2003)
6. O'Hare, G.M.P., Duffy, B.R.: Agent chameleons: Migration and mutation within and between real and virtual spaces. In: Proceedings of the Society for the Study of Artificial Intelligence and the Simulation of Behaviour (SSAISB) - AISB'02 Conference, London, England (2002)
7. O'Hare, G.M.P., Duffy, B.R., Schön, B., Martin, A., Bradley, J.F.: Agent chameleons: Virtual agents real intelligence. In: Proceedings of the Fourth International Working Conference on Intelligent Virtual Agents - IVA 2003. Volume 2792 of Lecture Notes in Computer Science., Irsee, Germany (2003) 218–225
8. Martin, A., O'Hare, G.M.P., Schön, B., Bradley, J.F., Duffy, B.R.: Intentional embodied agents. In: Proceedings of the Eighteenth International Conference on Computer Animation and Social Agents - CASA 2005, Hong Kong (2005)
9. Bratman, M.E.: What is intention? In Cohen, P.R., Morgan, J., Pollack, M.E., eds.: Intentions in Communication. MIT Press (1990) 15–32
10. Cohen, P.R., Levesque, H.J.: Intention is choice with commitment. Artificial Intelligence **42** (1990) 213–261
11. Rao, A.S., Georgeff, M.P.: Modeling rational agents within a BDI-architecture. In: Proceedings of the Second International Conference on Principles of Knowledge Representation and Reasoning - KR 91, San Mateo, CA, USA, Morgan Kaufmann (1991)
12. Collier, R., O'Hare, G.M.P., Lowen, T., Rooney, C.: Beyond prototyping in the factory of agents. In: Proceedings of the Third Central and Eastern European Conference on Multi-Agent Systems - CEEMAS'03, Prague, Czech Republic (2003)
13. Collier, R., Rooney, C., O'Hare, G.M.P.: A UML-based software engineering methodology for Agent Factory. In: Proceedings of the Sixteenth International Conference on Software Engineering and Knowledge Engineering - SEKE 2004, Alberta, Canada (2004)

14. Collier, R.W.: Agent Factory: A Framework for the Engineering of Agent-Oriented Applications. Phd thesis, University College Dublin, Ireland (2001)
15. Ross, R., Collier, R., O'Hare, G.M.P.: AF-APL - bridging principles & practice in agent oriented languages. In: Proceedings of the First International Workshop on Programming Multiagent Systems, Languages and Tools - PROMAS 2004, New York, USA (2004)
16. Anastassakis, G., Ritchings, T., Panayiotopoulos, T.: Multi-agent systems as intelligent virtual environments. In: Proceedings of Advances in Artificial Intelligence, Joint German/Austrian Conference on AI - KI 2001. Volume 2174 of Lecture Notes in Computer Science., Springer (2001)
17. Torres, J.A., Nedel, L.P., Bordini, R.H.: Using the BDI architecture to produce autonomous characters in virtual worlds. In: Proceedings of the Fourth International Working Conference on Intelligent Virtual Agents - IVA 2003, Irsee, Germany (2003) 197–201
18. Huang, Z., Eliëns, A., Visser, C.: Programmibility of intelligent agent avatars. In: Proceedings of Agent'01 Workshop on Embodied Agents, Montreal, Canada (2001)
19. Rist, T., Schmitt, M., Pelachaud, C., Bilvi, M.: Towards a simulation of conversations with expressive embodied speakers and listeners. In: Proceedings of the Sixteenth International Conference on Computer Animation and Social Agents - CASA 2003, New Jersey, USA (2003)
20. Marsella, S.C., Pynadath, D.V., Read, S.J.: PsychSim: Agent-based modeling of social interaction and influence. In: Proceedings of the International Conference on Cognitive Modeling - ICCM 2004, Pittsburg, Pensylvania, USA (2004)
21. Descartes, R.: Discourse on Method and Meditations. New York Library of Liberal Arts (1960) Edited and Translated by L. F. Lafleur from original French, first published 1637.
22. Brooks, R.A.: Intelligence without reason. In: Proceedings of the Twelfth International Joint Conference on Artificial Intelligence - IJCAI 91, San Mateo, CA, USA (1991) 569–595
23. Benford, S., Bowers, J., Fahlén, L.E., Greenhalgh, C., Snowdon, D.: User embodiment in collaborative virtual environments. In: Proceedings of CHI 1995. (1995)
24. Witmer, B.G., Singer, M.J.: Measuring presence in virtual environments: A presence questionnaire. Presence: Teleoperators and Virtual Environments **7** (1998) 255–240
25. Gerhard, M., Moore, D.J., Hobbs, D.J.: An experimental study of the effect of presence in collaborative virtual environments. In Earnshaw, R., Vince, J., eds.: Intelligent Agents for Mobile and Virtual Media. Springer (2002) 113–123
26. Fearon, J.D.: What is identity (as we now use the word)? Mimeo, Stanford University (1999)
27. de Levita, D.: The Concept of Identity. Mouton & Co. (1965) Translated by Ian Finaly from original Dutch.
28. Burchett, K.E.: Color harmony. Color Research and Application **27** (2002) 28–31
29. Taft, C.: Color meaning and context: Comparisons of semantic ratings of colors on samples and objects. Color Research and Application **22** (1997) 40–50
30. Vecchi, T., Girelli, L.: Gender differences in visuo-spatial prcessing: The importance of distinguishing between passive storage and active manipulation. Acta Psychologicia **99** (1998) 1–16