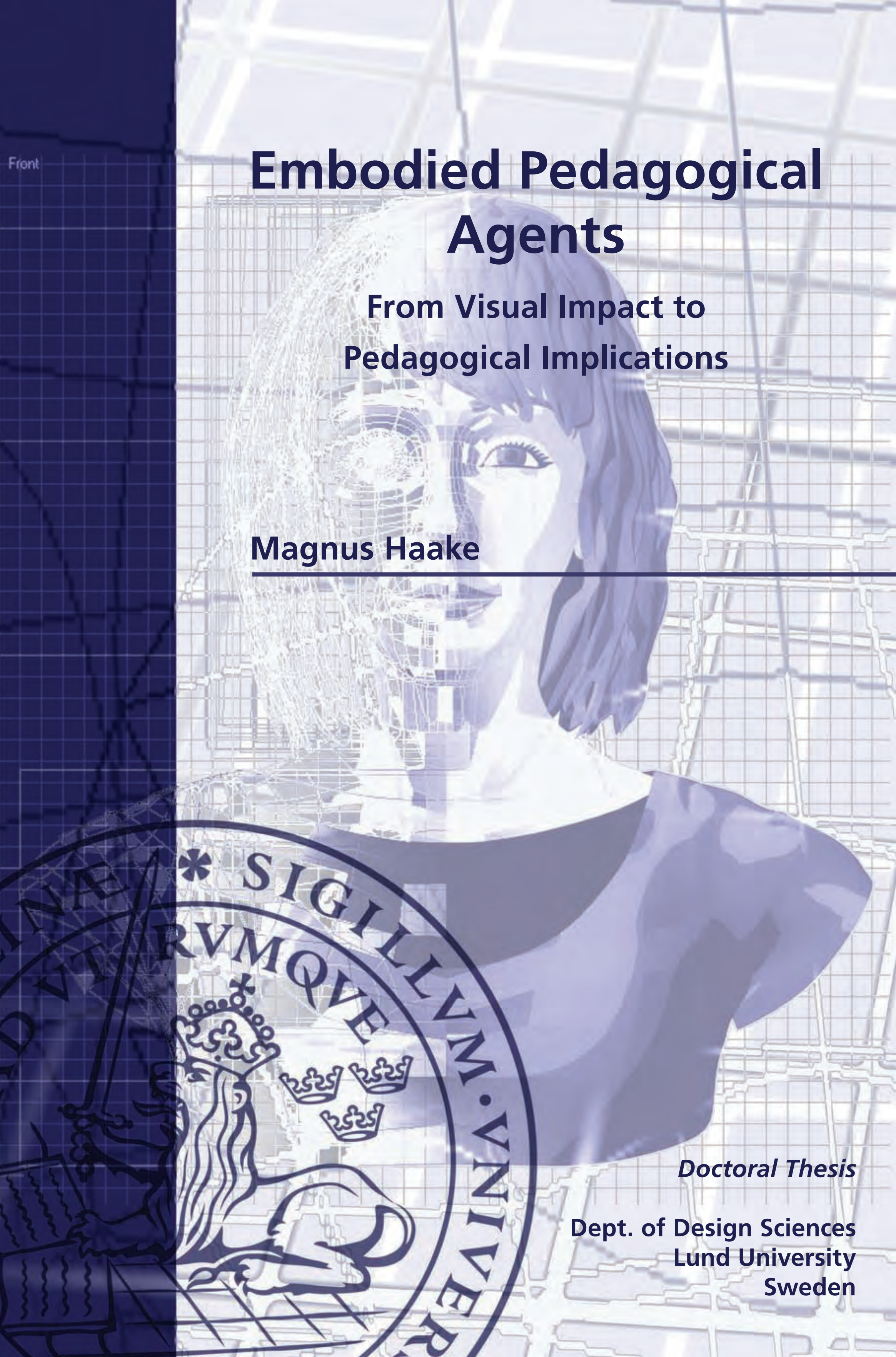


# Embodied Pedagogical Agents

## From Visual Impact to Pedagogical Implications

Magnus Haake

*Doctoral Thesis*

Dept. of Design Sciences
Lund University
Sweden

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# Part I

## Embodied Pedagogical Agents: an Overview

*This first part is a survey of embodied pedagogical agents, setting out on a journey from the hard computational roots of logic to socio-cultural implications.*

# *Introduction:*
# A New Social Actor

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## The Embodied Virtual Character – a New Social Actor

In the 1970s, a new kind of social actor saw the light – visually represented, computer generated *embodied virtual characters*. The immediate source of this was the advancement of video technology for visualizing animated virtual characters in commercial technical solutions. An immediate and important effect was that a larger group of people from then on had access to a digital arena and started to interact with (or mostly shoot down) these embodied virtual creatures such as the aliens in *Space Invaders* (Figure 1, left).

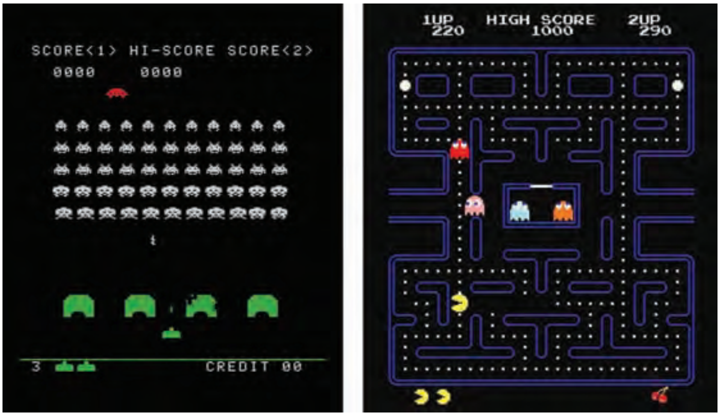


**Figure 1.** Left: *Space Invaders*® © Taito Corporation; Right: *Pac-Man*® © NAMCO BANDAI Games America Inc.

A step towards a more interactive and social embodied virtual character (or creature) came with the introduction of *Pac-Man* in 1980 (Figure 1, right). Pac-Man was a breakthrough in video game history, creating a whole new game genre and introducing an interactive (even if primitive) virtual world inhabited by 'hungry' virtual creatures. Furthermore, Pac-Man initiated an early gender busting effect as it came to appeal to both males and females (Lammers, 1986).


**Figure 2.** Top left: IKEAs chat bot *Anna* © Inter IKEA Systems B.V.; Top middle: *Sam* © GNL, MIT Media Lab; Top right: Avatars in *World of Warcraft*™ © Blizzard Entertainment, Inc.; Bottom left: *Laura* © MIT Media Lab; Bottom middle: *AutoTutor* © University of Memphis, TN, Bottom right: USA; Characters from *FearNot* © eCIRCUS.

Now, thirty years later, people all over the world interact with embodied virtual characters in the form of *avatars* in multiplayer online games like *World of Warcraft*, interactive chat bots like *IKEAs Anna*, and embodied pedagogical agents like *Laura*, *AutoTutor*, and *FearNot* agents – to mention a few (Figure 2). During these years, the embodied virtual characters have developed from simple low resolution creatures like Pac-Man to increasingly autonomous and 'intelligent' high resolution characters that can be experienced in digital games. Furthermore, with every new generation of digital characters, the border between reality and virtuality is slowly becoming more and more diffuse.

Already in this short introduction, terminology abounds with concepts such as: agent, avatar, chat bot, embodiment, etc. – and since this field is relatively young and divergent, the use of these concepts is far from consistent and stringent. In what follows, I establish the basic terminology to be used in this thesis. The starting point is a short historical résumé of artificial intelligence.

# *Chapter 1:* The Computational Heritage

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## Artificial Intelligence – the Root of it All

In this thesis, I discuss psychological, cognitive and social aspects of embodied virtual characters in pedagogical contexts. However, without the development and progress in *Computer Science* and especially the field of *Artificial Intelligence (AI)*, there would be no virtual embodied pedagogical characters to talk (or write) about from psychological, cognitive, and social perspectives. To establish a foundation for this thesis and its discussions, I will thus start from the beginning with the longstanding idea of an artificial being.

### A short pre-history of artificial intelligence

The idea of an artificial being can already be found in ancient Greek mythology, in the self-operating machines known as *automata* made by the divine blacksmith Hephaestus, as well as in the ivory statue of *Galatea* sculptured by Pygmalion and brought to life by Aphrodite (Crevier, 1993). These myths probably have even older precursors. From ancient Egypt testimonials originate of mechanical statues of the gods with deceit voice passages to the mouth, secretly controlled by priests (Brooks, 2002; Crevier, 1993). Later on through history there are many reports of artificial beings and artefacts, such as the *golem*, an animated artificial being in Jewish mythology.

In literature, Mary Shelley's *Frankenstein; or, the Modern Prometheus* (1818) became a milestone, shedding light on a fundamental topic in artificial intelligence: Can an artificial being have feelings? In his short novel, *I Robot* (1950), Isaac Asimov puts forth a set of ethics for robots which had great impact on later literature and film, as well as academia (Encyclopædia Britannica Online[1], 2009). Today, artificial intelligence is a well-known ingredient in popular media in numerous thrillers and science fiction movies like *Star Trek*, *Terminator*, *Alien*,

[1] *Encyclopædia Britannica Online*, henceforth abbreviated 'EBO'

*Blade Runner*, and *Matrix* (to mention a few). Notable is the recurrent conflict between (artificial) logic-rational reasoning and (human) emotional reasoning that is used as a both humorous and philosophical ingredient. One nice example is the internal logic-emotional conflict in the half human, half 'Vulcan' (alien) *Mr Spock* in the space odyssey series *Star Trek*.

Turning to actual implementations with relevance for the field of artificial intelligence, the mechanical clock (15th - 16th centuries) was a big step in the construction of mechanical devices and was soon followed by mechanical animals (16th century) and later on toys (18th century). In the meantime, Blaise Pascal constructed one of the first digital mechanical calculators in 1642-44. In the 19th century, Charles Babbage and Ada Lovelace worked on the principles for a programmable mechanical calculating machine (EBO, 2009).

The beginning of the 20th century saw the breakthrough of modern formal logic with seminal works like *Principia Mathematica* by Bertrand Russell & Alfred Whitehead (1910-13) and the prelude to modern computer science through names like Alan Turning (EBO, 2009).

During the mid 20th century, scientists from different academic fields (mathematics, psychology, engineering, economics, and political science, among others) began to discuss the possibility of constructing an artificial intellect. Shortly thereafter, forces united and the academic field of *Artificial Intelligence* is generally acknowledged to have been established 1956.[2]

**Artificial intelligence from 1956 to the present**

Artificial intelligence has had a turbulent history since 1956 – pendulating between periods of spiralling enthusiasm and paralyzing set-backs. The following résumé relies to a large extent on the book *AI: The Tumultuous History of the Search for Artificial Intelligence* by Daniel Crevier (1993).

***The initial hype***

The first period following the establishment of artificial intelligence as a field of research was enthusiastic and expansive. Supported by generous governmental funding, AI laboratories were founded at MIT, Carnegie Mellon and Stanford. Within a short time, new and seemingly astonishing computer programs were

[2] The academic field of Artificial Intelligence is generally acknowledged to have been established at the Dartmouth Conference of 1956. The proposal for the Conference included the following assertion: '*Every aspect of learning or any other feature of intelligence can be so precisely described that a machine can be made to simulate it.*' (Crevier, 1993, p. 48).

solving problems in algebra, proving logical theorems and speaking English. This initial success prompted optimistic prognoses like:

> *[M]achines will be capable, within twenty years, of doing any work a man can do. Herbert Simon (1956), quoted in Crevier (1993, p. 109)*
>
> *Within a generation [...] few compartments of intellect will remain outside the machine's realm – the problem of creating 'artificial intelligence' will substantially be solved. Marvin Minsky (1967), quoted in Crevier (1993, p. 109)*

However, the vision of actually putting together an artificial intellect was (and is) all but humble, and the initial hype eventually faded away. The early programs that seemed so astonishing could in many cases only operate at very trivial levels with well-defined framings in relation to the problems they set out to solve. There were several reasons for these disappointments, among others:

- The problem of intractability and the combinatorial explosion, that is the fact that many problems exhibit a logarithmical explosion of alternatives to evaluate, outnumbering the capacity of even a utopian super computer.
- Another problem was to be called Moravec's paradox. Contrary to earlier assumptions, the human ability for conscious, logic-rational reasoning requires comparatively little computation, whereas the unconscious senso-motoric skills and instincts require enormous computational resources.[3]

These two problems led to another main problem of AI: How does everyday reasoning function? The early approach was to regard human reasoning as high level, formal symbolic reasoning, but the failure of the first AI hype to model functional algorithms to solve complex problems gave way to theories of human reasoning in terms of unconscious, intuitive, emotional and embodied 'know how' rather than 'symbol processing'.

### *The first AI winter and the second hype*

By the mid 70s, the generous undirectional governmental (and military) funding in both the UK and the USA were drastically cut due to disappointment with the meagre outcome as to functional systems. This was the first 'AI winter'.

One of the branches of AI that survived during coming years was *expert systems* (programs that simulated the knowledge and analytical skills of one or more human experts). In the early 80s, expert systems went into commercial success and

[3] In Moravec's own words: '*[I]t is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility.*' (Moravec, 1988, p. 15).

AI research experienced a revival. However, as an ironic joke about the difference between the rational (AI) and the emotional (humans) – AI research was caught in a second spiralling hype of unrealistic expectations.

### *The second AI winter and AI after the mid-90s*

By the end of the 80s the limitations of expert systems started to show. Even though an expert system might, for example, be more accurate in diagnosing than most physicians, it could suddenly miss a diagnosis by miles if a situation was not foreseen and implemented. Part of the explanation for this relates to the problem of common sense reasoning, which remains one of the persistent AI problems. An expert system can only have knowledge of a relative limited and specified world, which makes it very vulnerable to situations that touch or expand the border of the defined knowledge domain (i.e. the *Frame Problem*). These knowledge constraints also makes it very difficult for an expert system to make holistic common sense judgements whether – as in the example above – a diagnosis is plausible or not. [4]

Fair or not, once again hyped expectations ended in drastic cuts in funding, resulting in a second and longer AI winter – and still today AI, as an academic field of its own, suffers from this disrepute.

At the same time, behind the scenes AI has attained broad success with powerful algorithms that solve difficult computational problems in other areas of technology such as data mining, industrial robotics, regulatory systems ... and not the least computer games.[5] Probably the major consequence of the second AI winter was that AI was fragmented and joined other research fields where it continued under new names like knowledge-based systems, computational intelligence, and intelligent agents. New multidisciplinary research fields also emerged including intelligent virtual agents, affective computing, and educational technologies, that all have a bearing on this thesis. The next chapter deals with the definition of intelligent virtual agents and the somewhat confusing terminology in the field(s).

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[4] For example: *MYCIN* (Stanford University) was an early medical expert system for treating blood infections. It performed roughly equal to human specialists in blood infections and better than general physicians. However, if it were told that a patient (who had received a gunshot wound) was bleeding to death, the program would attempt to diagnose a bacterial cause for the patient's symptoms (EBO, 2009).

[5] To quote a colleague (Björn Breidegard, Certec, Lund University): '*Artificial intelligence? You know, everyone is fiddling with it – but no one admits it.*'

# *Chapter 2:*
# From Intelligent Agents to Embodied Pedagogical Characters

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## The 'Intelligent Agent'

First of all, keep in mind that we are basically dealing with computer algorithms (i.e. program code that generates experiences of simulated virtual beings). Secondly, we need to disentangle the fundamental concept of an 'agent'.

### Agents

The notion of an 'agent' may take on a multitude of interpretations depending on the context – but let's start with a dictionary definition.

> **1:** one that acts or exerts power
> **2 a:** something that produces or is capable of producing an effect : an active or efficient cause b: a chemically, physically, or biologically active principle
> **3:** a means or instrument by which a guiding intelligence achieves a result
> **4:** one who is authorized to act for or in the place of another: as **a:** a representative, emissary, or official of a government <crown *agent*> <federal *agent*> **b:** one engaged in undercover activities (as espionage) : spy <secret *agent*> **c:** a business representative (as of an athlete or entertainer) <a theatrical *agent*>
> **5:** a computer application designed to automate certain tasks (as gathering information online)
> *Merriam-Webster Online Dictionary (2009)*

Of these standard definitions, the first two with their emphasis on action and effect are of particular interest: '1: one that acts or exerts power', and '2a: something that produces or is capable of producing an effect'.

In the domain of Computer Science, the notion of an agent (or *software agent*) on the other hand generally adheres to the last definition above: '5: a computer application designed to automate certain tasks'.

Combining these interpretations of an agent, this thesis defines 'an agent' as 'a software application capable of operating on its own and of performing action'.

### Intelligent agents

A specific group of software agents are denoted 'intelligent agents' or 'autonomous agents'. This corresponds to software applications that 'behave' more or less autonomously and with some kind of decision capacity or intelligence. For example, computer viruses, worms, and other forms of computer malware may operate on their own with different strategies in order to infect computers (thereby causing trouble like their biological counterparts). Accordingly, an intelligent agent can be seen as a digital actor, operating in a digital environment – and though this notion of an intelligent agent is situated in a virtual, digital context, its actions and behaviours may affect and continue in the real world (like the effect of a computer virus causing a hard disk to crash.)

In this thesis, the concept of an intelligent agent is even more delimited with respect to the focus on computer generated, humanlike characters. The intelligent agent in this case represents an immaterial computer application with simulated humanlike, cognitive capabilities[6] such as perception, communication, planning, reasoning, learning, decision making, and emotions. To be able to implement such applications, one needs to engage solutions and strategies from the field of artificial intelligence.

Following this reasoning, an intelligent agent is defined as 'a software application with an ability to act on its own and to reproduce human behavioural and cognitive capacities by means of artificial intelligence'. However, (since the breakthrough of artificial intelligence, mimicking human abilities always seems to be predicted to come twenty years in the future) we will in practice be satisfied with all kinds of 'tricks of the trade' in order to provide an ever so faint experience of interaction with another living existence. The shorter term 'agent' consequently (in this thesis) also denotes a computer application that may behave as an intelligent agent, but without any actual artificial intelligence employed, in that the perceived intelligent behaviour of the agent is based on simple sets of predetermined conditions or similar strategies.

Summing up, the concept of an 'intelligent agent' is associated with or encompasses ideas of digital technology, virtuality, autonomity, intelligence, interaction,

[6] In this thesis, 'cognition' takes on the broad interpretation from cognitive science, encompassing a wide range of human aspects related to thinking and behaviour, not the least emotions. This is in contrast to cognitive psychology where cognition often is used to refer to the 'intellect' in contrast to motivation and emotion.

and living, but it does not necessarily encompass aspects such as embodiment, character, and visualization.

**Embodiment**

In Cognitive Science, theories of embodied cognition challenge the idea of the human brain as an isolated and independent intelligent entity. In short, embodied cognition proposes that the human mind is largely determined by the human body. All aspects of human cognition, such as reasoning, communicating, decision making, and perception have evolved under the constraints of the evolution of the human body and its capacities (e.g. Brooks 1999; Dourish, 2001). In this approach, the idea of an isolated brain is meaningless. Without access to perceptual channels and a body, the brain would in a short time deflate and eventually pass away.

In line with the theories of embodied cognition, a pure self-operating intelligent agent would be of limited interest for the scope of this thesis. A virtual character requires some means to communicate. An early and simple method was command line keyboard input together with screen text output, which was hardly successful for a broader public in terms of efficiency and smoothness. As humans, we are by evolution specialized to communicate with other humans by means of spoken language, facial expressions, body language, tactile/physical contact, and not the least, olfaction.[7] Furthermore, humans appear as a very egocentric species, eager to anthropomorphize both living creatures and lifeless objects. Consequently, an anthropocentrically oriented interaction with an intelligent agent could benefit from the potential richness and flexibility of human communicative strategies. Following this line of reasoning to its end, the optimal embodied intelligent agent is a robot not distinguishable from a human.

At least in the near future, much of this is still pure science fiction. What we can do is to render animated graphical representations of human beings, creatures (or whatever) on a display ... or build spectacular robots for the entertainment industry. By this we access some of the potential power of facial expressions and body language in addition to the more immaterial qualities of spoken language, such as a face in which to embed the spoken message with a smile or subtle wrinkles around the eyes – the ever so important context.

Doing so, we may obtain a visual intelligent agent with the communicative potential power of embodiment. However, human communication is not spoken language and gestures alone – we also make heavy use of mental conceptualiza-

[7] Some theories of human cognitive evolution emphasize the development of social interaction and language as main driving forces (e.g. Whiten & Byrne, 1997).

tions like preconceptions, stereotypes, and social constructions in order to situate, contextualize, and facilitate communication (even if this is a double edged sword). An embodied intelligent agent will automatically be loaded from the start with ideas, preconceptions, and stereotypes invoked by its visual body as well as its voice (see also Part II, Chapter 8).

To sum up, with the embodiment of the intelligent agent, we have the basic foundation of a 'new social actor' – *the embodied virtual character* – presented in the first lines of this thesis. Next, I present an outline of the diverging branches of embodied virtual characters and associated terminology.

## Embodied Virtual Characters and Conceptual Confusion

### Avatars, agents, bots (and mannequins)

Depending on the approach, two main categories of embodied virtual characters can be identified. One is the 'avatar', which is controlled by a human and used as her or his virtual representation in a digital arena (e.g. the characters used in online games like *World of Warcraft*).

The second main category is the character that can 'act' on its own and 'react' on user input/contextual input. This is the 'intelligent agent' (or 'autonomous agent') discussed above. In everyday use, the shorter form 'agent' is common when the experience of a computer generated (intelligent) agent is more in focus than the implementation of any actual 'intelligent' algorithms. The 'bot' is also included in this second category, and may be defined as an 'intelligent agent' situated in an Internet context. For example, there are embodied 'chat bots' that can answer questions and assist in other ways like the virtual assistant *Anna* on IKEAs web-site (see Figure 2). There are also the 'chat bots' that are designed to simulate intelligent conversation with humans

Outside the scope of this thesis are the 'virtual mannequins'. These are digital versions of mannequins used, for example, in computer supported ergonomic design of driver environments, computer simulated crash tests, virtual reality oriented medical education ... and they are (of course) now also used in fashion design.

### Conversational agents

Conversational agents constitute a branch of intelligent agents designed to simulate conversation in natural language by means of artificial intelligence (with echoes of the old *Turing Test* of artificial intelligence, originally set up as a natural language test mediated by keyboard and screen interaction.)

Embodied conversational agents constitute one of the dominating fields of embodied intelligent agent research, which also appropriated an abbreviation of its own: *ECAs*.

From the perspective of the anthropocentric embodied intelligent agent domain, natural language involves the embodied and contextualized aspects of facial expressions and gestures. In line with this, the overall goal of the research on embodied conversational agents is a smooth and natural interaction. However, while natural language generation has made quite impressive progress when it comes to synthetic speech – natural language understanding remains bothersome and the general input method is still the keyboard.

**Affective & relational agents**

***Affective agents***

Another vivid research domain overlapping the domain of intelligent agents is affective computing (Picard, 1995), which focuses on technologies that can recognize, evaluate, respond to, and generate emotionally related information. For example, there are systems that collect and analyze physiological data like heart rate frequencies, eye movements, and voice characteristics. These data are then evaluated based on an emotional model of a human (bored, confused, engaged, etc.), upon which an appropriate system response is calculated.

Such systems belong to the field of artificial intelligence under the name of 'affective systems'. Consequently the corresponding agents are categorized as intelligent agents under the name of 'affective agents' (i.e. intelligent agents that can detect and react upon a user's emotional state and behaviour). Adding a body gives us embodied affective agents that are able to express humanlike emotions by means of a happy smile or eyes filled with sorrow.

***Relational agents***

Relational agents make up a subgroup of affective agents (Bickmore & Cassell, 2001). These are intelligent agents designed to develop and maintain long time socio-emotional relations with users. They can save memories (data) of past interaction sequences with the user which then can be processed in combinations with computational models of long time humanlike relational processes.

**Pedagogical agents**

This category – which also is the focus of this thesis – addresses intelligent agents that have a pedagogical agenda. Historically, they originate from a long tradition of intelligent tutoring systems (ITS) emerging during the 1960s (c.f. Chapter 3).

Since then the power and complexity of tutoring computational models have evolved, paralleled by technological advances in computational power. Given this development, along with the preceding survey on intelligent agents and embodiment, it is no surprise that pedagogical systems during the 1990s started to explore embodiment and the potential of social and relational contexts. This development has also been influenced by the growing awareness of socio-cultural aspects in pedagogy, something that will be further discussed in Chapter 4.

In this thesis, the focus is on embodied intelligent agents in pedagogical settings. They will be denoted *embodied pedagogical agents (or characters)*, with the term 'pedagogical' being more constrained and specific then the broader term 'intelligent'.

To finish this terminological review which (with some deviations) has led us to embodied pedagogical agents, one can in a more straightforward manner define them as 'visually represented, computer generated characters in pedagogical roles, such as virtual instructors, mentors and learning companions, encountered in different digital environments' (c.f. *Paper III: Haake & Gulz, 2009, p. 39*).

**Embodied virtual characters in general**

As indicated, virtual characters (in the sense of computer generated, visible, more or less humanlike characters) have become an increasingly important ingredient of virtual environments. In order to better understand these novel arenas, the terminology reviewed above can help to:

i) distinguish between avatars (that are controlled by a user) and agents (that are controlled by a system),
ii) identify and distinguish between conversational, affective, relational, and pedagogical agents, and
iii) recognize 'embodiment' as an expansion to intelligent agent systems that adds the potential of embodied human social communicative strategies.

Additionally, one should mention that the notation 'agent' more often is used when one wants to emphasize the intelligence and autonomy of an (embodied) virtual character. Correspondingly, the notation 'character' is more often seen when focusing on the embodiment. The notion 'character' is furthermore often used in a more comprehensive sense, encompassing all the diverging variations of visually represented, computer generated, humanlike artefacts (intelligent or not).

Turning to the broader literature, one may encounter notions such as: animated agent/character, synthetic agent/character, interface agent/character, etc. In accordance with the preceding classifications, these notations are – more or less deliberately – used to emphasize certain attributes. Thus, an 'animated character' may be used to emphasize the qualitative aspects of animated characters, with a focus on algorithms that generate gestures and movements in real time. This is not to be confused with an 'animated character' in, for instance, a Pixar/Disney movie. These latter characters are pre-rendered animations belonging to a fix story, with no interaction, flexibility or intelligence whatsoever. However, such characters, pre-rendered into sets of alternative, optional, combinable sequences, may comprise the underlying embodiment of intelligent agents. They can also be used as test dummies in order to examine, for example, the social and communicative effects in the interaction between humans and embodied characters in the role of artificial social actors.

## Intelligent Agents vs. Embodied Pedagogical Characters

As has been described, there is a multitude of different computer based intelligent humanlike artefacts, ranging over a vast spectrum. To wrap up this chapter, I will recapitulate what distinguishes them from each other – and what unifies them.

- *Complexity:* How complex and flexible are the algorithms and models that control and/or generate the behaviour?
- *Real time generation:* Does the system use pre-rendered materials, and in what ways?
- *Humanlikeness:* How humanlike is the appearance, movements, gestures, and behaviour?
- *Input:* What kind of input is used (keyboard text input, spoken language and voice characteristics, visual signals such as facial expressions and gestures, physiological data, etc.)? How flexible and complex are the algorithms and models that recognize and evaluate this input?
- *Output:* What kind of output is used (text on screen, voice and sounds, facial expressions, body language, etc.)? How complex and rich is this output?
- *Interaction:* How rich and advanced is the interaction (communication) between human and agent? That is to say, what potentials and constraints are there for any mutual influence regarding the dialogue and behaviour of the user and the agent respectively?

## A Final Reminder ...

Writing and reading about embodied intelligent agents may prophesy a fantastic and impressive as well as a terrifying and scary future, but as far as artificial intelligence is concerned, we are far from being able to simulate or understand human cognition in its broad sense.

**... or Two?**

Embodied pedagogical agents are not going to replace teachers, but hopefully help them to personalize the learning during the everyday activities.

# *Chapter 3:* Artificial Intelligence and Learning

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## Artificial Intelligence and Learning – an Historical Résumé

The use of technology to support or assist pedagogical activities is probably as old as pedagogy itself – at least if the use of a stick to punish lazy youngsters can be seen as a use of technology. A more meaningful example is the use of primitive tools to preserve and recapitulate objects and ideas as graphical pictograms and ideograms. Later on in history, the gradual evolution of modern writing systems and the technique of using parchment and paper are indeed cases of technology supported learning – followed by the invention of the printing press. In modern history, it is interesting to note how new technologies immediately generate new ideas of technology supported learning. A splendid example is the granting of radio broadcasting licenses to colleges, universities, and school boards by the US federal government from the 1920s to the 1940s. The venture ended in a total failure only to be carried on to the new media of television (Nasseh, 1997).

The present-day, rapid development in information technology has consequently generated lively activity involving research and development around technology supported learning. Comprehensive notions like *e-Learning* (*electronic Learning*) and *Educational Technology* signify broad fields that embrace all kinds of digitally computer related ideas and applications connected to pedagogic issues. When it comes to this thesis, the main focus is on the branch of artificial intelligence known as *Intelligent Tutoring Systems* (*ITS*).

### Intelligent tutoring systems (ITS)[8]

Among ideas and applications following the first boom of artificial intelligence in the 1960s was that of intelligent machine assisted learning. As a branch of

[8] This part on Intelligent Tutoring Systems (ITS) builds on Haake (2006) and Crevier (1993).

artificial intelligence, it has followed the general progress and ups and downs in this field (c.f. Chapter 1). An initial approach was to provide students with a personal and individualized *intelligent tutoring system* (*ITS*), constructed around three components: domain knowledge (knowledge of the specific subject), student model (a way to 'understand' and interact with the student), and teaching knowledge (pedagogy). In this way, the system would be able to survey a student's actions and progress, provide feedback and give contextual advice and support for problem solving.

The early systems that emerged during the 1960s and early 1970s were relatively simple, and the main innovative power was perhaps the development of user interaction techniques such as video screens, keyboards, and speech synthesizing. The intelligence was based upon domain specific data, organized in databases with relatively simple rules for the interaction, prompting the student through static tutoring plans. The learning situations were thus much on the terms of the systems, and eventually the general problems in artificial intelligence to progress beyond the initial achievements also affected the research and development of intelligent tutoring systems.

Following the revival of artificial intelligence with the expansion of expert systems during the 1980s, the intelligent tutoring systems took a leap forward with the development of computational models for the user/student and pedagogic strategies. Then again, as the problems of further expanding the models of human cognitive capacities into more advanced and complex models were severely underestimated, research and development within intelligent tutoring systems levelled out.

After this, the AI branch of intelligent tutoring systems transformed under influences from other fields such as pedagogy and human-computer interaction. Today, with the expanding potential of graphical user interfaces and video graphics, the old idea of intelligent tutoring systems is a part of the novel and vivid research fields of *e-Learning* and *Educational Technology* mentioned above.

## Present-day Artificial Intelligence in Learning

### A cognitive approach to artificial intelligence and education

As suggested above, the early rational track of artificial intelligence, inspired by theories of modern formal logic, could not provide any substantial computational models of human cognition or human learning. This disappointment eventually brought the rational paradigm and the idea of making artificial 'human' intelligence into disrepute.

Since then, there has been a growth in theories of embodied cognition and an increasing awareness of affective and emotional aspects of human cognition. Today, a more multifaceted picture has emerged of a gradually evolved human cognition, situated in a complex and dynamic reciprocal system of brain and body, as well as a surrounding world and culture. This view of cognition as inherently embodied and situated is far from the earlier formal and rational traditions in science (see Chapter 5).

**Artificial intelligence in education**

Concerning artificial intelligence, these new perspectives of embodied and situated cognition have led to new approaches manifested in computational fields such as affective computing. Here we also find the technological roots of embodied virtual characters in their guise as social actors in digital learning systems.

# *Chapter 4:* Technology Supported Social Learning

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## Social Learning

In present-day pedagogy, a view on knowledge as socially constructed is integrated in central pedagogical theories. This approach emphasizes the processes of teaching as well as of learning as inherently social, involving interaction, communication, negotiating, and sharing (Gulz, 2004; Gulz & Haake, 2009)[9].

The obvious contrasting example is the idea of a prototypical learner as a student in a study chamber, employed in an individual intellectual pursuit of reading and writing. However, for the everyday student, learning is probably better described as a dynamic alternating process of socially oriented learning activities (lectures, group assignments, co-studying, etc.) together with periods of more individual endeavours of reading and reflection.

An important aspect of social learning is the recognition of the physical place (e.g. classrooms, group rooms, and cafés) as an arena that both initiates and supports social activities.

## Lessons from Distance Learning

While technology can be designed to support social group activities like multiple user workplaces (Dillenbourg, 1999), the development of distance learning technologies over the Internet has received much attention. The most simple form is more or less a transcription of the older mail correspondence courses based on written instructions and assignments passing back and forth. A well-known concern with this basic form of distance learning is the relatively high percentage

[9] This is neither a new nor anarchistic idea. The antique Academy of Plato was in much built around the philosophical dialogue, which truly is a social approach to learning (EBO, 2009).

of students that sooner or later drop out, never finishing the course (Tyler-Smith, 2006). With the exception of the obvious unrealistic expectation of being able to set off time for home studies while working and raising a family, the absence of a social context in the actual learning situation may well be an important factor. It can be argued that social relations in the form of teachers and fellow students provide a social framing that scaffolds continued studying even when it becomes quite demanding. One can here speculate about rewarding social affordances like 'studying together with fellow students' and 'getting help with difficult parts' as well as avoiding social distress like 'not disappointing the teacher' and 'not being excluded from the community of fellow students'.

## Educational Technology and Social Learning

Educational technologies are only tools, but they are flexible ones. This potential to be flexible and the awareness of social dimensions and emotional factors in learning have led to a strong attention on technological supports that situate learning in social contexts. Scanning the fields of Educational Technology and e-Learning brings forth themes such as: social learning in multimedia, enabling social presence in virtual environments, personalized web companions, computer-supported social interaction, character enhanced systems (Gulz, 2004).

To address social learning contexts in educational technologies, two main strategies can be distinguished (*ibid.*). In *extrinsically social learning systems*, the role of the system is to provide room and support for social activities, which are created and supplied by the learners (e.g. distance learning systems with discussion forums and online chats). The contrast is *intrinsically social learning systems*, where social interaction and context is provided within the system by means of social arenas populated with social actors, for example *The Exercise Advisor Laura* (Bickmore, 2003) and *FearNot* (VITEC/eCircus).

Extrinsically social systems are in their basic form relatively easy to develop as they can be built on standard solutions for mail services, discussion forums and online chats. Intrinsically social systems, on the other hand, must deal with social interaction in other ways, which often means advances algorithms and complex architectures by means of artificial intelligence.

Another important difference between these two kinds of systems that must not be forgotten regards the single user. The extrinsically social system requires at least two users for social interaction to take place, whereas the intrinsically social learning system in itself can engage a single, individual user in social interactivity with a single, individual user.

## The potential of Intrinsically Social Learning Systems

Both extrinsically and intrinsically social environments have their potentials as well as problems, and one can of course consider systems employing both strategies to a greater or lesser extent. The following discussion focuses on the potential of intrinsically social learning environments that support social interaction by means of embodied pedagogical agents.

Since intrinsically social learning systems have the specific quality to engage a single, individual user in social interaction, it is possible to adapt such a system to the changing needs of an individual student. The system can thus be tailored with regard to teaching strategies (troublemaker, challenger, co-operator), roles (coach, instructor, companion), and so on. With regard to the daily classroom situation, the social prerequisites as to classmates and teachers are relatively constrained. However diligent a teacher may be, it is simply impossible to meet every individual student based on that student's personal needs as to learning style and need for personal attention. From this perspective, the intrinsically social learning system can be a complement to a teacher with the potential to engage in dynamically tailored learning without any restrictions as to time.

### Character enhanced intrinsically social learning systems

#### *Proposed benefits of character enhancement*

The possible benefits of character enhanced intrinsically social learning systems are all but systematically explored and the results are often ambiguous. With this reservation, there are several proposed advantages and Gulz (2004) lists and discusses six kinds of benefits that can be seen as central for character enhancement. They are summarized below with some updates and will be followed by a discussion as to empirical evidence:

i) *Increased motivation:* Character enhancement may prompt students to stay on and involve themselves in a learning environment by means of motivation. Central factors that may increase motivation are experiences of entertainment, likeability, and engagement. Other factors often related to motivation are the lifelikeness of the character, the 'Persona Effect'[10], and the ability of the character to show and elicit emotions (e.g. Lester et al., 1997; Moreno 2004; Moundridou & Virvou, 2002).

[10] The 'Persona Effect': That the presence of a lifelike character can have strong (positive) effects on students' perception of their learning experience (Lester et al., 1997)).

ii) *Increased sense of ease and comfort:* The addition of social characters may have a positive relaxing effect on the student, making her or him feel more comfortable and more at ease with the learning tasks and the learning environment (e.g. Moundridou & Virvou, 2002; van Mulken et al., 1998).

iii) *Stimulation of essential learning behaviours:* Learning can be described as the employment of different basic strategies and the presence of a social actor may have a positive stimulating effect as to exploration, cooperation and reflection (e.g. Blair et al., 2006; Johnson et al., 2003). Attention, as elusive as it may be, is an important and central concept in learning. From the perspective of social learning, character enhancement may have the potential to capture and increase, as well as guide the attention of the learner (e.g. André et al., 1998; Rickel & Johnson, 2000).

iv) *Enhanced flow of information and communication:* Building on the idea that humans are evolutionarily fine tuned with regard to social interaction with other humans, a social actor with human-like communicative capabilities may pave the way for a smooth, rich and efficient flow of information. A central aspect of this approach is the importance of facial expressions and body language to reinforce, clarify, and consolidate the spoken dialogue as well as to provide feedback (e.g. Cassell & Thorisson, 1999; Massaro et al., 2000; Oviatt & Adams, 2000).

v) *Gains in terms of memory, problem solving and understanding:* Positive effects in terms of improved memory, problem solving, knowledge transfer, and understanding may follow from character enhancement (e.g. Blair et al., 2006; Johnson et al., 2003; Moreno et al., 2001).

vi) *Fulfilling the need for deeper personal relationships in learning:* Finally, in addition to prompting, encouraging, and scaffolding different behaviours and experiences as to learning, a social actor may also promote experiences of deeper personal relations. In the form of relational agents (see pages 13) it is possible to establish and even maintain long-term qualitative personal relationships between a student and a social learning system (e.g. Bickmore & Picard, 2003; Moreno et al., 2001; Veletsianos & Miller, 2008).

***Empirical support for the benefits of character enhancement***

When it comes to empirical support for the listed benefits of character enhancement, there is a general problem in the absence of long-term studies.[11] The absolute majority of studies are short-term, often evaluated by means of quantitative

[11] Among important exceptions one can find Bickmore (2003) and Veletsianos & Miller (2008).

measures. The quality of these studies is often problematic as to what is actually measured in combination with problematic interference effects between different benefits and short-term effects of novelty (e.g.'Hawthorne effects')[12] (Dehn & van Mulken, 2000; Gulz, 2004).

Another problem in the empirical outcomes is the omission to examine the distribution of positive or negative effects in relation to distinct groups. Instead there is a tendency to merge the test group into an averaged user (see Chapter 5). More explicitly, by correlating the examined group as to communicative style, pedagogical style, gender, etc., one can find one group showing positive effects and appreciation as to social interactive learning and one group with negative responses and irritation as to the presence of social actors (e.g. Bickmore, 2003; *Paper III: Haake & Gulz, 2009*). These findings will be further discussed in Chapter 8 where the papers included in this thesis this thesis are presented.

Finally, the empirical outcomes (even though ambiguous) support an optimistic approach to character enhancement in intrinsically social learning systems. The results do not suggest that one should think of character enhancement as a general solution for social learning – but as a support for certain students where the potential positive effects of social characters relate to the individual learner and the specific learning situation. This also implies the important potential of computer based pedagogical systems: The same learning material can be presented in different ways, with or without social context, and – in the case of social character – with characters differing and tailored to different needs and situations.

## Summary: Technology Supported Social Learning

There is much in favour for the endeavour to develop technology supported social learning systems. When it comes to the prospect of actually developing systems capable of inducing the possible benefits, one should remember that we are far from being able to simulate or understand human cognitive and communicative capabilities.

[12] The 'Hawthorne effect': The Hawthorn study sought to identify those aspects of a job that were most likely to boost worker productivity. At the study's onset, it was thought that economic factors would have the greatest influence on productivity. The results were surprising: productivity increased, but for reasons unrelated to economics. Ultimately, researchers concluded that job performance improved because more attention [i.e. the study (*author's comment*)] was being paid to the workers (EBO, 2009).

At the same time, social learning and character enhancement in pedagogical systems is not merely academic research. There have been several more or less advanced commercial systems around for a good while. Thus, considering the severe knowledge gap as to long-term use of character enhanced social learning systems, it is not necessarily due to the underlying technology – but rather to an unfortunate lack of systematic studies.

# *Chapter 5:* The Troublesome Concept of Rationality

*The concept of rationality is as old as science itself. Basically, any field of modern academic science is bound to articulate its knowledge and research by means of rational (logical) coherent reasoning.*

*At the same time, the phenomena of study in modern science (except for some disciplines in natural sciences) are seldom accessible and describable as strict logic-rational systems. At best they may subdue to statistical probabilities, but often enough the articulation of knowledge resides within multiple and even ambiguous argumentative and descriptive perspectives.*

*To me, this implies a scientific paradox: Science (as a whole) is bound to articulate its knowledge by means of rational reasoning, though the phenomena of study seldom will fall apart into rational describable models.*

## About Rationality

The domain of embodied virtual characters is intimately connected to computer science and artificial intelligence and, accordingly, the domain as a whole is computationally oriented. This is only natural, as there would be no embodied agents without the continuous development of even more complex and sophisticated algorithms in addition to the constant increase in computational power.

At the same time, the domain of embodied virtual characters is a cross-scientific field, combining artificial intelligence with fields like cognitive science, social psychology, linguistics, neurobiology, and graphic design. This inevitably leads to a variety of approaches and – perhaps more troublesome – diverging views on the scientific issue of rationality.

## A short history of rationalism

In Western science, the Greek heritage has imposed the pervasive idea that all phenomena ultimately are addressable by rational (logical) reasoning. For instance, Aristotle's work on logic (syllogism) and his argument that humans are 'rational animals' have had a tremendous impact. This rationalistic aspiration has manifested itself throughout history in endeavours to access by reason the world, the human mind, and the existence of God (e.g. philosophical rationalists[13] like Descartes, Leibniz, and Kant). Omnipotent as well as impressive, these projects were in the end only mental constructs – but they have continued to nourish the philosophical-scientific community of the 20$^{th}$ century. Influential philosophers of logic and mathematics (e.g. Frege, Russell, Wittgenstein, and Gödel) made groundbreaking contributions in the rationalistic traditions and set the foundation of modern formal logic and programming (c.f. Chapter 1).

At the doorstep to the second half of the 20$^{th}$ century, science as a practice seemingly relied on a firm and stable ground of rational reasoning and experimentation.[14] Soon, however, postmodernistic critique and deconstruction inundated the scientific community, digging trenches between scientific disciplines.

## The non-rational, rationalizing human

Eventually, as the problems and set-backs of the rational analytical approaches to human cognition in fields like artificial intelligence (c.f. Chapter 1) and cognitive psychology (see below) have piled up, the old scientific assumption of the 'rational human' can hardly be upheld in science today.[15] One way to deal with this dilemma is concisely expressed in a quotation from the science fiction writer Robert Heinlein, '*Man is not a rational animal; he is a rationalizing animal.*' (Heinlein, 1953, 14). This approach can be described as follows:

1) Humans have no dedicated logical-rational cognitive processing modules in the brain. That is to say, humans do not process (logical) information in ways similar to electronic logical circuits.
2) Humans can behave in a logical-rational manner, given certain conditions.

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[13] Rationalism: the philosophical view that regards reason as the chief source and test of knowledge – holding that reality itself has an inherently logical structure (EBO, 2009).

[14] However, already in the first half of the 20th century, the inherent limitations of formal logic and mathematics had been demonstrated by, for example, Gödel (*incompleteness theorems*) and Ramsey, Church and Turing (*undecidable problems*) (EBO, 2009).

[15] An interesting argument for the non-rational human is given in Johansson et al. (2005) where they cleverly exposed the human feebleness for introspectively derived reasons when failing to detect mismatches between intention and outcome, an effect they call choice blindness.

The first argument (1) relies, among others, on recent theories of human evolution and embodied and situated cognition (Clark, 1999; Lindblom & Ziemke, 2003). The second argument (2) is easily exemplified with everyday mathematical problem solving.

The benefit of this alternative view of human cognition is that it may open up new perspectives and approaches, especially in research disciplines constrained by explicit or implicit assumptions of human rationality.

**Rationalism and artificial intelligence**

Regarding artificial intelligence, the field was born in the positivistic academic atmosphere of the mid 20$^{th}$ century. From the beginning it was tightly connected to the new branch of cognitive psychology, which was approaching human cognition by means of implicit rational model building – such as the persistent hypothesis that human decision-making could be accessed by formal models (Sahlin, Wallin & Persson, 2009).

Thus, given the academic society of the time, it is no wonder that the belief in the potential of formal logic rationality and human rationality was so strong at the onset of artificial intelligence.

> *It is not my aim to surprise you – but the simplest way I can summarize is to say that there are now in the world machines that think, that learn and that create. Moreover, [...] the range of problems they can handle will be coextensive with the range to which the human mind has been applied.*
> *Herbert Simon (1957), quoted in Crevier (1993).*

As argued in earlier passages of this thesis, many aspects of human cognition are not accessible or solvable by formal logic. At the same time, the inherent nature of computation is a logical manipulation of formal symbols. For embodied virtual characters as a research field, this implies a somewhat paradoxical situation of non-rational rationality.

## The Rationalistic Approach and Its Consequences

Taking a closer look at the field of embodied virtual characters, let us propose a hypothetical rationalistic agenda – (i) and (ii) below – and then explore the consequences of this agenda with respect to applied artificial intelligence in education (c.f. *Paper I: Gulz & Haake, 2006a*).

i) The quest for the 'perfect' artificial human.
ii) The concept of 'the user'.

***The quest for the 'perfect' artificial human***

Following a long tradition of philosophy and science, one of the ambitions of artificial intelligence is to uncover human cognition with the overriding aim of constructing a 'perfect' artificial replication of a human being (i.e. an embodied agent and eventually a robot or cyborg). This is science *per se*, striving for knowledge for the sake of knowledge itself.

In present artificial intelligence there may be a dilemma as to the possible implicit concept of the 'rational human'. In a field this focused on rational computational models of human cognition – there is an augmented hazard with regard to the scientific (and human) tendency to mistake the map for the territory.

***The concept of 'the user'***

In order to enable human-agent interaction, there is a need to implement computational models of the intended human user. Such user models are often *generalized* models of human cognition. Real humans, on the other hand, exhibit an *individual diversity* with respect to cognitive and emotional behaviours and an astonishing flexibility as to communication. To engage in social interaction with other humans means to guess, negotiate, reconsider, fill in, make mistakes, confirm, correct, etc. (Hansson et al., 1979).

Once again, there is an apparent risk to mistake the map for the territory. The everyday case with single (general) user models may transfer to the evaluation situation and a treatment of test groups as generalized single humans. As a consequence, evaluations risk missing significant correlations as to, for example, cognitive sub-groups of pedagogical and communicative preferences (e.g. *Paper III: Haake & Gulz, 2009*).

***Applied artificial intelligence in education.***

The two discussed dilemmas could be regarded as internal issues, but they are not. The field of educational technology is directed towards functional and efficient applications and systems. What if the agendas of (i) and (ii) above will not do the trick? What opportunities are there today or in the near future to implement functional and efficient applications of, for instance, embodied pedagogical agent systems?

Another concern is the view of contextual phenomena when employing an embodied pedagogical agent to interact with a human learner. A cartoonish rendering of an embodied pedagogical agent with an emphasized, caricatured personality and pedagogical profile would be far from a realistic simulation of a real human being. On the other hand it may prove very efficient for interactive social learning (c.f. Chapter 8 and *Paper I: Gulz & Haake 2006a*, *Paper III: Haake & Gulz, 2009*).

Both these concerns imply a shift from the agenda to simulate 'real' human communication, towards a focus on algorithms that may scaffold and even augment human-agent communication. Actually, a contextual perspective of this kind may have even more dramatic consequences than a change as to the computational problems of interest. It may even (in some cases) erase the need for new computational approaches all together.

**The computational trap ...**

The development of a computational algorithm to control the smile in a virtual face can easily diverge into increasingly more complex computational real-time models. An alternative approach is to turn to social psychology that can provide evidence that modifications of a face itself (as to gender, age, attractiveness, etc.) may totally change or overrule the effect and quality of the smile algorithm. The task at hand will then shift from (i) a development of a computational algorithm to control the transition of vertex points in a mesh to (ii) a matter of graphic design to model 'by hand' a face that is appropriate as to holistic and contextual aspects (e.g. support clear human facial expressions, handle socio-cultural impact on visual design, experiment with different graphic and artistic interpretations). Eventually, there may not even be a need for a new and better computational algorithm.

**... and cultural aspects**

Different perspectives regarding computational (rational) approaches and cultural aspects of human-agent interaction is another topic to discuss. The effect of appearance and voice on the cognitive processes may not be readily accepted, but is nevertheless empirically well established. To pick an example, there is much research that supports the halo effect (i.e. that good-looking people are attributed other positive traits such as being sociable, intelligent, and interesting, whereas unattractive people are considered less socially competent, dishonest, and psychologically unstable) (Brigham, 1980; Langlois et al., 2000). Similarly, socio-cultural effects also adhere to voices. In their book, *Wired for Speech*, Clifford Nass and Scott Brave (2005) convincingly demonstrate how cultural constructed conceptions relate to voice characteristics such as gender, dialects, and sociolects.

## Rationality and Embodied Pedagogical Agents

Within modern academic science, as a common societal endeavour, the articulation of knowledge and research by means of rational coherent reasoning can be regarded as a fundamental prerequisite. Also a visually oriented domain as design (in its academic form) eventually aligns with the rational discourse to be able to discuss and argue around design objects, demonstrators, and design concepts.

Rationality is also an insidious concept. The necessity to align with rational reasoning in the explicit articulation of knowledge may easily be confused with an implicit idea of a rational universe, where all phenomena are inherently understandable and describable by means of rational reasoning.

The lesson (to easily forgotten) is: '*Never mistake the map for the territory*'. Science is model building – the ultimate 'Truth' is something else.

The practical consequences of this perspective on 'rationality' with regard to the field of embodied pedagogical agents, can be summarized as follows: The research on embodied pedagogical agents, as a cross-scientific field, has a built-in tension between: (i) implicit rational disciplines like artificial intelligence, (ii) relativizing and constructivistic socio-cultural fields of social interaction and communication, and (iii) non-academic practices like graphic design. If asking for trouble, it is there to be found – but from another perspective there are magnificent challenges to deal with.

Finally, it is not a question of right and wrong. All perspectives have their strengths as well as shortcomings and complement each other. It's a question of proportions ... and watching out for the rational ghost.

# Part II

## Embodied Pedagogical Agents: From Visual Impact to Pedagogical Implications

*Part II presents a summary of the five papers appended to this thesis, with a main focus on the visual impact of embodied pedagogical agents with regard to pedagogical implications. Concerning details and in depth reasoning, I refer to the appended papers which represent the actual scientific work behind this thesis.*

*I also want to add a personal remark. The research presented in this second part is an inherently joint endeavour by me and my wife and colleague, Agneta Gulz, covering some seven years of a variety of projects and studies. We have also had much valuable help of several master students.*

# *Chapter 6:*
# A Graphical Design Space of Embodied Pedagogical Agents

**{:-)**

*As argued in Part I (Chapter 5), more design-oriented aspects of embodiment such as appearance often fall outside the computational practice. Yet these are aspects that form our first impressions and influence the human-agent interaction.*

*In order to handle such aspects, I begin this second part of the thesis with an outline of a graphical design space of static visual characteristics of embodied pedagogical agents. (The version outlined here is a summary of the framework presented in Paper III.)*

## Visual Aspects of Embodied Pedagogical Agents

### Dynamic and static visual characteristics

First of all, visual appearance can be divided into the two sub-categories of *dynamic visual characteristics* and *static visual characteristics*. The dynamic visual characteristics relate to animated expressions mediated by facial displays, body and hand gestures, postures, movements, etc. The static visual characteristics refer to visual aspects of the underlying character, for example, face and body shapes, hair, clothes, attributes, colours, and graphic style.

### The problematic static visual characteristics

From a pedagogical perspective, there is reason to believe that the visual characteristics of an agent may considerably affect learner expectations, attitudes, understanding and motivation (c.f. Chapter 4). Similar influences are well known in related domains such as theatre, film animation, advertising, as well as in social psychology (e.g. Gard, 2000; Lassetter, 1987; Schneider, Hastorf & Ellsworth, 1979).

In the field of embodied agent research, the importance of dynamic (computational) visual aspects is generally agreed upon and much effort has been directed to research and development with respect to facial expressions, gestures, and movements.

In contrast, the static visual characteristics have received relatively sparse attention, which may be due to their non-computational nature (c.f. pages 29-32). A consequence of this neglect is that static visual characteristics often are approached in a simplified manner that overlooks the complexity of visual aspects and eventually results in misconceptions and problematic over-generalizations.

With regard to this problematic neglect, the aim of this chapter is to present an outline of a graphical design space of static visual characteristics of embodied pedagogical agents.

(*A more elaborated discussion of these topics can be found in Chapter 8.*)

## Design Dimensions of Static Visual Characteristics

The static visual characteristics constitute an immense and complex multidimensional design space that may be described as a set of more or less elusive, changing, context-dependent qualities. Such a perspective can hardly be submitted to any kind of rational, analytical deconstruction and the focus thus needs to be on high-level design aspects. In order to relate to this multidimensional design space, a comprehensive framework will be laid out with three basic high-level design considerations (with regard to static visual characteristics of embodied pedagogical agents): *basic model*, *physical properties* and *graphical style*.[1]

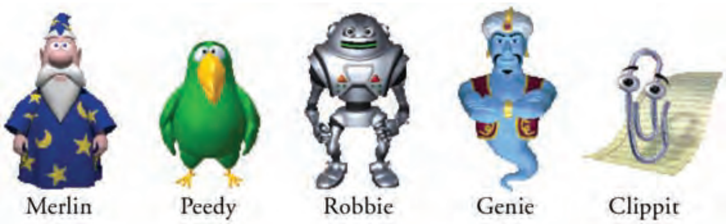


**Figure 3.** The characters from the *MS Agent Package* and the *MS Office Assistant* exemplifying the proposed basic model: *Merlin* (a human); *Peedy* (an animal/creature); *Robbie* (a combination of a human, inanimate parts, and a fantasy concept); *Genie* (a combination of a human and a fantasy concept); *Clippit* (an inanimate object).

[1] These design considerations are partly elaborated from the discussions of a more integrated design approach for virtual characters reported in Gratch et al. (2004) and further developed in Ruttkay et al. (2004).

### Basic model

The first high-level design topic to consider is the *basic model* or constitution of a character (an embodied pedagogical agent), which can be described in relation to four basic conceptual entities: *a human*, *an animal or creature*, *an inanimate (non-living) object*, *a fantasy or fiction*, or *a combination of these entities* (Figure 3).

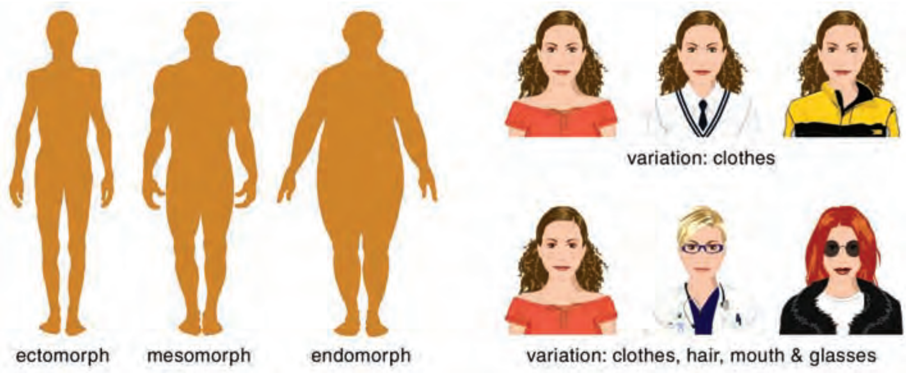


**Figure 4.** Examples of physical properties. Left: the three body types of *ectomorph*, *mesomorph*, and *endomorph* identified by Sheldon et al., (1940). Upper right: three different outfits transforming the experience of the one and same character as to personality, social position, education, etc. Lower right: variations of the same character by means of outfit, hair style, hair colour, use of lipstick, and use of glasses, dramatically changing the experience of the character. (The six characters to the right were put together by means of the *SitePal Demo Tool*, www.sitepal.com.)

### Physical properties

The second high-level design topic addresses *physical properties* such as: body type, face shape, skin colour, hair cut, hair colour, clothes and accessories (Figure 4).

An important aspect of this second design topic is that the physical properties of an embodied pedagogical agent (as well as a human) always carry social, cultural, psychological and affective baggage, that is, there is no such thing as a *visually neutral* character (e.g. *Paper IV: Gulz, Ahlnér & Haake, 2007*; *Paper II: Haake & Gulz, 2008*; Isbister, 2006).

## Graphical style

The two previous high-level design topics can to some extent be analytically approached and described. This is more difficult with the third high-level design topic of *graphical style* (Figure 5).

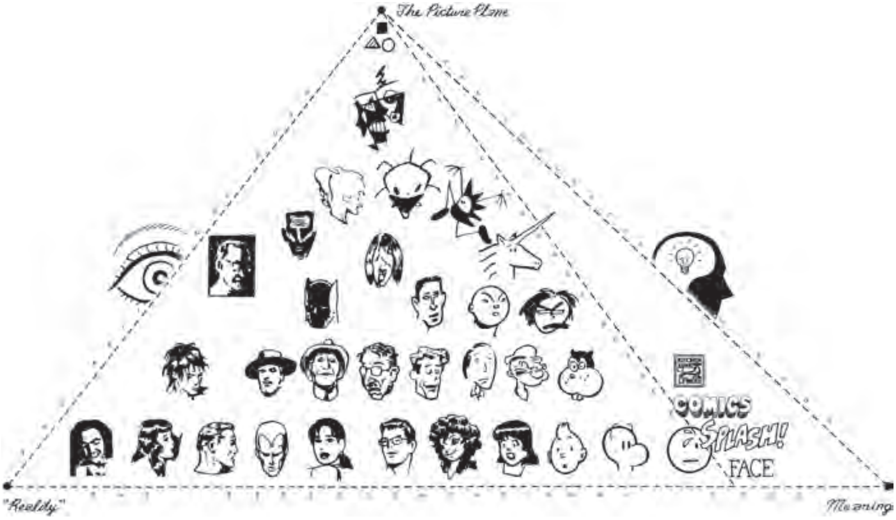


**Figure 5.** An edited reproduction of the design space of visual iconography (*The Big Triangle*) described by Scott McCloud in his book *Understanding Comics* (McCloud, 1993). While this is an ingenious way to set up the design space of graphical style, there is no predictable power to correlate a certain graphical style to a well-defined response.

Here one enters the full complexity of the graphical design space where small changes in, for example, the qualities of the line (Figure 6), shadings, and proportions may completely change the visual and cognitive experiences in diverse and not the least unpredictable directions (McCloud, 1993).

In spite of this, some aspects of graphical style may be both possible and worthwhile to explore. With regard to embodied pedagogical agents, there are at least two aspects of interest: *degree of detailedness* and *degree of naturalism*.

## Graphical style: degree of detailedness

A regular photo of a face is highly detailed. By straightforward means of reduction, such a photo can be transformed into a contour line representation or a two level posterized representation of the very same face (Figure 7, left). In everyday design practice, however, a reduction of details usually goes hand in hand with more complex changes and modifications of the graphical expression or style (Figure 7, right).

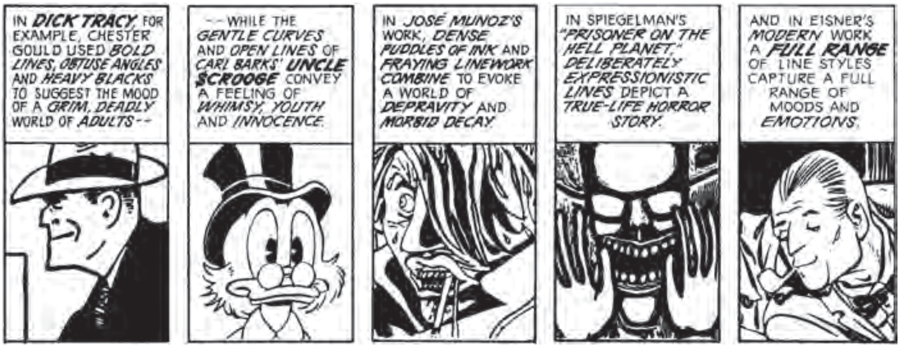


**Figure 6.** The inked line has almost unlimited possibilities with a potential of tremendous visual power (McCloud, 1993, p. 126).

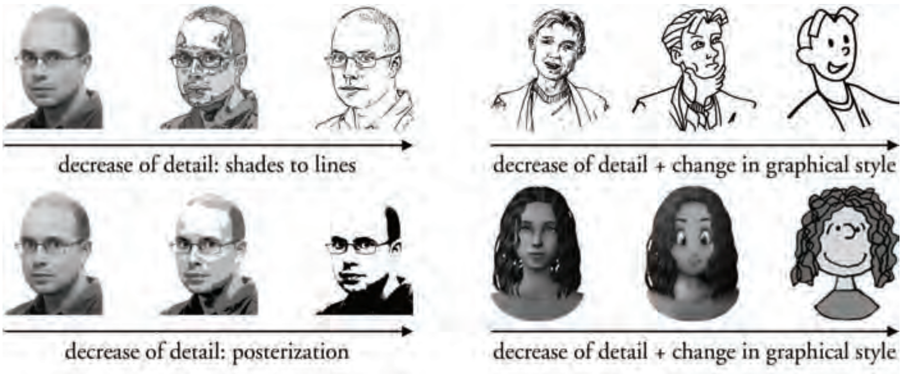


**Figure 7.** Graphical style: degree of detailedness. Left: two examples of straightforward reductions of details; Right: two more complex examples where reduction of details are combined with divergent (non-computational) changes as to graphical style.

The degree of detailedness affects cognitive processing. For example, the reduction of details can promote increased distinctness of facial expressions which may support a more rapid and accurate processing and interpretation (e.g. Cook, 1979; Isbister, 2006). This simplification may also (as discussed in more detail in Chapter 8), facilitate subjective self-identification.

**Graphical style: naturalism vs. stylization**

The same conceptual character, with respect to its basic model and physical properties, may be visually represented in numerous variations (Figure 8). By manipulating the qualities of line, shape and colour – each single variation (graphical style) may convey its own complex, dynamic, cultural and context dependent impact on the unique interpretation processes of the individual perceiver.

A constructive approach with regard to pedagogical effects can be to collapse the design space into a two dimensional map of *naturalism* and *stylization*. Naturalism here constitutes a well-defined endpoint of an otherwise immense and diverging design space of different stylized graphical expressions (Figure 8).


**Figure 8.** A design space of naturalism-stylization. The two figures to the left (the naturalistic endpoint) differ in degree of detailedness (c.f. Figure 7, left) but both are referred to as rather naturalistic. This design space is derived out of the pictorial plane (*the Big Triangle*) by Scott McCloud (1993) but is simplified in order to emphasize the dichotomy of naturalism vs. stylization (c.f. Figure 5).

The four stylized representations in Figure 8 above vary in expressive style inspired by: *Peanuts* (simplified, whimsy and humorous); *Dragonball* (cute, emotional and friendly); *Hernandez* (underground, rebellish); *Picasso* (abstract and intellectual).

*Note:* this simplified design space (Figure 8) does not convey any actual information about realative cognitive effects between different kinds of stylization – something that seems out of reach (at least from an academic perspective).

# *Chapter 7:* What About Realism?

**: -?**

*Relying on the framework of a graphical design space of embodied pedagogical agents just outlined – it is now time to approach the concept of visual realism.*

*(This abbreviated presentation is based on a discussion to be found in Paper III.)*

## A Definition of a Realistic (Human) Embodied Agent

Considering the embodied agent literature, the term 'visual realism' or 'visually realistic' is used in remarkably diverging and confusing ways. In an attempt to grasp a common concept of a *realistic (human-like) embodied agent*, I propose the following definition:

i) modelled upon the basic model of a 'prototypical' human
ii) adequate and relevant as to physical properties of a 'prototypical' human
iii) fully detailed (no reduction of detailedness)
iv) naturalistic (not graphically stylized).

The underlying problem is that many studies, when presenting their material and conclusions, neglect to specify what is actually meant by the term 'realism' (or 'realistic'). Sometimes the comparisons regard a character modelled upon a human versus a character modelled upon a fantasy concept, though both are perfectly naturalistic in relation to their basic models and could be equally realistic given a fictive context of a science fiction movie (Figure 9). On other occasions, the difference is in the degree of detailedness, yet combined with differences related to naturalism-stylization that are, however, neither recognized nor problematized. Despite such lack of deeper and more detailed analyses, the results are often generalized in terms of 'visual realism' versus 'visual non-realism'.

**Figure 9.** A study by van Vugt et al. (2007) compared three settings: non-character, realistic character (left), and un-realistic character (right). The hypothesis was that there would be effects of 'design-realism', but the effects of the two characters (above) did not differ. (In the framework of this thesis, the characters differ with regard to: basic model, clothes, and graphical style (soft rendering vs. facets).

**Figure 10.** The interactive information assistant Olga (developed by KTH, SU, SICS & Nordvis AB).

An illustrative example is reported by Gustavsson and Czarniawska (2004). At a conference, there was a discussion on the development of the interactive assistant *Olga* (Figure 10). The linguists in the development team opted for a more realistic Olga, since they insisted that in order for Olga's speech to be understood, Olga must be made as humanlike as possible. Olga's lip movements, in particular, had to correspond to those of a living human. The designers in the development team, on the other hand, were of the opinion that the comic styled Olga was actually more humanlike and attractive than the more realistic 3D-Olga, who they thought looked like Frankenstein's monster (an opinion shared by most of the conference audience).

The point of this example is that *none* of the Olgas (Figure 10) are realistic but instead constitute two different visually stylized representations that both could be referred to as:

i) modelled upon the same combination of a human and a fantasy concept of an alien from outer space,
ii) comparable as to physical properties (with the exception of the neck and the tie),
iii) rather comparable as to a low degree of detailedness,
iv) differences as to graphical style: 2D rendered, a bit squarish/angular shapes, some visual freedom as to postures *versus* 3D rendered, a bit softer/rounder shapes, constrained (stiff) as to postures.

This example indicates that the notion of realistic is (often) more of a non-reflected idea than an actual and explicit visual quality ('*If it's 3D, it's realistic!*').

**The underlying problems**

The underlying problems regarding the (mis)conception of realism are at least two:

i) The concept of realism is used without definition or specification (as discussed above).
ii) The confusion falls back upon a deeper problem: a widespread ignorance concerning 'deeper' aesthetic/graphical qualities and their relation to human experience (as seen in the Olga-example above).

In most studies, the inherent graphical qualities of the presented characters are not problematized. That is to say, the studies employ rather arbitrary representations, for example, one arbitrary 3D rendered character is compared to another arbitrary cartoonish character. Thereafter the results are generalized to the whole groups of 3D characters and cartoonish characters respectively.

The point is that all too often the representations exhibit uncontrolled and unproblematized variations as to the graphical framework presented above – not the least when it comes to artistic qualities. For example, as with the study of van Vugt et al. (2007) commented on in Figure 9, there are many possible factors involved in the comparison between a relatively standarized and normal 3D rendering and an rather odd representation. The difference in such a case probably lies more in the artistic qualities. The comparison regards a kind of standard soft 3D rendering of a business character with a suite versus a faceted 3D rendering of an artistically quite bizarrely composed un-realistic(?) fantasy character with odd clothes. What then is really measured?

(The same reasoning can be applied to the study on androgyny by Nowak & Rauh (2008) presented in the next chapter (page 52).

# *Chapter 8:* From Visual Impact to Pedagogical Implications

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*With the presentation of a graphical design space and a discussion on the use of visual realism, it is now time to present an overview of the central research topics and the corresponding findings in the papers included in this thesis.*

## The Importance of Visual Aspects

The research behind this thesis started more than seven years ago, when it soon became obvious that visual or graphical issues – as to the basic appearance of the embodied agent itself (i.e. the *static visual characteristics*) – were often left out in computational oriented approaches such as: user modelling, animation algorithms for gestures, facial expressions and gaze, language processing, and affective computing. In particular, comparative studies that systematically varied these visual aspects were hard to find (*Paper I*). At the same time it seemed unlikely that visual aspects should not have an impact on the experience of embodied pedagogical agents given the collected experience and knowledge in practices like computer games, films, performing arts, and cartoons. Furthermore, there was also an abundance of empirical evidence in social psychology (*Paper I*).

As discussed in Part I, the field of embodied (pedagogical) agents is inherently connected to artificial intelligence and computational approaches. In such contexts, visual appearance and similar considerations might sometimes be seen as amusing tinkering with aspects outside the scientific scope. A personal reflection is that this mirrors the trap of the rational paradox (page 31). Visual design of embodied (pedagogical) agents is not accessible or describable by means of rational models or schemas (or computational 'rational' algorithms) and thus visual design falls outside the scientific scope of the field.[2]

Today, empirical results that address aspects of visual design and the impact on the experience of the interactive embodied agent are no longer 'that odd' in the community of embodied (pedagogical) agents. There is also additional support in experiments demonstrating that aesthetic factors can have a positive impact on cognitive tasks (e.g. Norman, 2002; Lavie & Tractinsky, 2004).

## The impact of physical appearance

### *Findings from social psychology*

For a good while now, there has been ample evidence in social psychology[3] that the appearance and observable physical cues of other people profoundly affect our judgements. It has also been shown that similar responses apply to embodied virtual (pedagogical) agents (*Paper I-V*).

**Figure 11.** Disney has long excelled in the reproduction (and production?) of stereotypical instances such as *the princess* (*Paper I*).

An interesting argument for the impact of visual appearance is its role in the representation of personality. Branham (2001) borrows the drama theory term 'physical personality' of a character to refer to the aspects of appearance, which immediately and with no acquaintance, produce an impression of personality, and which initiate a set of attitudes and expectations. Among those aspects are many visual aspects such as body shape, height, gender, race, physical attractiveness, hair, make-up, clothing, and so on. Noteworthy is also a quotation from Berscheid & Walster (1974): '*[O]ur appearance telegraphs more information about us than we would care to reveal on a battery of personality inventories […]. From flame-coloured hair through flat feet, few aspects of appearance fail to provide kernels of folk insight into another's nature.*' (*ibid.*, p. 159). The crucial issue is that regardless of how accu-

[2] To quote the (early) Wittgenstein: '*Wovon man nicht sprechen kann, darüber muss man schweigen.*', (Ludwig Wittgenstein, Logish-philosophische Abhandlung (Tractatus Logico-Philosophicus), 1921, Proposition 7). Note, however, that this statement was later rejected by the (latter) Wittgenstein. (In English: '*Whereof one cannot speak, thereof one must be silent.*', Translation by C. K. Ogden.)

[3] E.g. Schneider, Hastorf, & Ellsworth (1979; Schneider (2003).

rate such insights are, people do build them. In folk psychology this is recognized in idiomatic warnings such as: 'Don't judge a book by its cover.' (*Paper I*).

Furthermore, impressions of other people's personalities based on physical appearance may not only persist, but even increase over time (Mathes, 1975). Once again, in folk-psychology, you find notions like: '*First impressions are lasting.*' (*Paper I*).

Given the assumption that people fall back on social strategies when interacting with embodied agents in ways similar to real life interaction (Reeves & Nass, 1996), it is an intriguing idea that a principle like, 'First impressions are lasting' may bear upon embodied agents as well.

#### *Evidence of visual impact of embodied pedagogical agents*

An illustrative example regarding the effects of visual impact in the use of embodied pedagogical agents is reported by de Rosis et al. (2004). A virtual character was designed for a natural-language interface for a legal information system. Initially the character was designed as a very attractive young female assistant, since the developers assumed that the typical users of the system were going to be male lawyers. However, after realizing that the lawyers' (female) secretaries were the ones who most frequently used the system, they became aware that the appearance and behaviour of the character disturbed these users. Thus, they designed a new character, with more classical attire and a more professional communication style (*Paper I & II*).

## The Power of Simplification (iconization)

### A question of communication

The discussion on rationality in Part I (Chapter 5) contained a passage on computational and cultural considerations with regard to the embodiment of virtual agents (pages 31-32). An aspect of that discussion addresses the issue of resource demanding naturalistic 3D rendering versus simplified cartoon rendering in the presentation of embodied agents. Given the steady technical progress, issues of real time 3D rendering may only be a matter of time. On the other hand, as proposed in the discussion, there is more to visual presentation than computational power. The main objective for an embodied pedagogical agent is to engage in social interaction with the learner and thus strengthen the social and communicative features of a pedagogical system. This means that the basic concerns have to address the qualities of the pedagogical interaction (communication) itself, that is, how do different visual representations relate to positive pedagogical effects such as motivation, stimulation, ease, flow, problem solving, understanding, etc. (c.f. Part I, Chapter 4).

**Simplification (iconization)**

The concept of simplification in the embodied (pedagogical) agent domain addresses the possible benefits of using a simplified (iconized) visual representation for the agent (Figure 12), (c.f. Chapter 6 and Figure 7).

**Figure 12.** Degrees of simplification (iconization) from highly stylized (left) to near naturalistic (right), (see also Figure 7).

There are several arguments pro and con the idea of simplification, some claiming that pictorial realism (i.e. naturalism) is a necessary condition for meaningful human co-operation with an animated agent (e.g. Welch et al., 1996; Nass, Isbister & Lee, 2000).

Outside the world of embodied agents, comic artist and writer Scott McCloud (1993) argues – in contrast – that subjective audience involvement can be increased by iconization. According to McCloud (*ibid.*), people will more easily get involved with and also be likely to project themselves into a visually simplified character than a highly detailed and naturalistic character. The highly detailed and naturalistic character is more of a visual and socio-emotional fact (an object associating to 'the other'), which does not leave much for a user to elaborate on and fill in. A stylized character, on the other hand, invites subjective identification and elaboration by the user, who may fill in from his or her own personal and subjective experiences. In McCloud's wordings, the stylized character is '*[A]n empty shell that we inhabit.*' (*ibid.*, p. 36).

The underlying mechanism brought forth by McCloud (*ibid.*) is that the concept and image of oneself (subject) is highly iconic in contrast to that of other people (objects) in one's environment. Therefore, identification and social affinity with an agent come more naturally and effortlessly in response to a simplified (iconic) agent. This, in turn, may increase the impact that the agent has on users (*Paper I* and Figure 13).

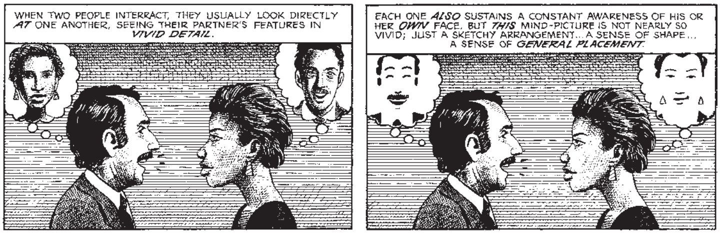


**Figure 13.** People who interact experience each other's faces in a detailed, realistic manner, whereas they only have a schematic, iconic representation of their own faces (McCloud, 1993, p. 35-36). © Scott McCloud & HarperCollins Publishers, Inc.

## Iconization vs. naturalism

A direct pedagogical implication of the reasoning above can be exemplified with a virtual teacher in contrast to a virtual learning companion. If the design consideration of iconization-naturalism is applied, the teacher character (relating to an instance of the other, an object) might benefit from more naturalism in the representation. A learning companion character (with the potential of a subjective identification with 'oneself') may, on the other hand, benefit from a more simplified (iconized) representation (*Paper I-III*).

So far the theoretical reasoning. When it comes to empirical findings, the picture gets more complicated with diverging results in different studies. Part of this confusion often lies in very weak and non- reflected interpretations of the confusing concept of visual realism as discussed earlier (Chapter 7). In addition, we also find generalizations neglecting further contextual aspects as, for example, graphical style in relation to pedagogical role (as in the example above).

In one of our own studies (*Paper III*) we included 'pedagogical role' and 'communicative style' as contextual variables. The results of the study supported the idea that iconization may correspond to pedagogical role and communicative style.

Referring to anecdotic references from both studies and the domain of computer games, I would here like to speculate on two further factors: (i) *age dependence* in that younger students (first to sixth grade) may have a preference for more stylized (cartoonish) characters, and (ii) *artistic and graphical qualities* as to total experience and communications of emotional states. In the latter, the graphical style of *Manga* [4] (with explicit techniques for emotional expressiveness) has seen worldwide success.

[4] *Manga* has come to represent a widespread graphical style, though the actual meaning of the word is 'Japanese comics' (or literally: 'aimless pictures'), (EBO, 2009).

**Iconization, similarity attraction, and role modelling**

Other aspects of simplification (iconization) relate to identification issues: *similarity attraction* and *role modelling* (*Paper V*).

***Similarity attraction***

Similarity attraction has proved to be a working factor in embodied pedagogical agent settings. Lee & Nass (1998) report on participants perceiving an agent to be more socially attractive, trustworthy and intelligent when there was an ethnical match. Another example is the case with the legal information system presented on page 47.

More recent effects of similarity attraction are reported by Baylor, Rosengard-Kima & Plant (2006). In an engineering tutorial, young female students were most strongly affected as to motivation and self-efficacy regarding engineering subjects by virtual coaches that were similar to themselves (or similar to how they would like to be) – in this case female, young and cool (Figure 14).

**Figure 14.** The virtual coach (young and cool female) used in Baylor, Rosengard-Kima & Plant (2006).

This points at a dilemma in embodied agent design. One solution is to design multiple agents to always have one that may work on the basis of similarity attraction. This may, however, underpin negative aspects of group mentality in terms of 'we and them' or alignment to detrimental stereotypical behaviours. An alternative approach may be to design simplified (iconized) characters with a lesser degree of visual clues as to ethnicity, body constitution, social status, etc. (This seems to be Disney's recipe in recent years, where ethnic markers as skin tone are held back (Engholm, Michelsen, 1999).)

***Role modelling***

Role modelling is another fruitful concept in the research of embodied pedagogical agents. Opportunities for role modelling are known to strengthen development in pedagogical terms (Bandura, 1977).

One parameter that is known to influence the strength of a role model is attractiveness. If a role model is perceived as attractive the behaviour of the model is more often imitated (Rommes et al., 2007). Studies by Baylor and her collaborators (Baylor & Plant, 2005; Baylor, Rosenberg-Kima & Plant, 2006) have highlighted the importance of images and alternative cultural role models for engineering students. Also other researchers have suggested that more physically attractive and glamorous female role models might change the negative prototypes of computer scientists (Coltrane and Adams, 1997).

In comparison with traditional pedagogical media, virtual settings provide specific potentials for role modelling and identification. By offering a broad range of alternative pedagogical characters with regard to visual style, personality, and social identity, it can be possible for a larger number of students to identify with a virtual pedagogical character (find a role model) and to engage in the learning task.

However, the use of role modelling is complex and comprises hidden dilemmas. For example, the connection between role modelling and visual stereotypes comes forth in the article by Baylor, Rosengard-Kima & Plant (2006) in which it was demonstrated that the use of virtual pedagogical coaches portrayed as *young and attractive females* (see Figure 14) can increase the willingness of female students to apply for technical courses and help to increase their self-efficacy. At the same time it was found that these positive results stemmed from a conception of a 'female, feminine, young and attractive' engineer as less competent than a 'real, typical male engineer'. The prejudice that females, and in particular females with a more pronounced feminine appearance, are less competent in technical domains seems to spill over to the virtual area, generating increased self-efficacy of the kind '*If she is able to do it, I can do it!*'

This implies a potential conflict between a short-term pedagogical goal of recruitment and boosted self-efficacy in female students, and a long-term pedagogical goal of changing rather than reproducing gender prejudices and stereotypes.

### Simplification and androgyny

Thus, similarity attraction and role modelling can have both positive scaffolding as well as negative detrimental effects. Is there a way to 'have your cake and eat it'? In *Paper V: Gulz & Haake (in press)* we investigated the possibility of using androgyny to counter detrimental effects of gender prejudices.

Androgyny is a complex issue. Not being able to decide whether someone is a man or a woman is known to induce insecurity and unease in many people (Brave and Nass, 2005). Attractiveness (mentioned above), however, can be a factor here due to its role in well-functioning role models and cultural images (Rommes et al., 2007). In addition to this, attractiveness may even overrule the 'unease' of androgyny (Hess, 2007).

By designing the pedagogical characters in a naturalistic, but simplified form and thereafter render them in a 'flat' posterized visual graphical style (c.f. Figure 7, left) – we could manipulate and express aspects of androgyny and attractiveness in combination with a satisfying visual (aesthetic) result (Figure 15, left).

This simplified graphical style of the characters might furthermore facilitate identification and thus counter the 'unease' of androgyny … and as for the results, the study gave reason to believe in this possibility (see pages 61-64).

**Figure 15.** Left: Androgynous agents used in *Paper V: Gulz & Haake (in press)*; Right: Androgynous avatars used in Nowak & Rauh (2008). Note that the two left agents share the same basic 3D mesh. The main differences are the clothes and hair, with only minor modifications as to make-up (lips, eye liners, and eye brows) and light angle.

In a widely noticed study by Nowak & Rauh (2008) the authors argued that androgyny decreases avatar credibility. However, the study has shortcomings as to the actual avatars that were evaluated and therefore the generalization that are made of the results is unsupported (Figure 15, right). Referring to the Gulz & Haake study above, there are several visual factors beside androgyny that may count for a decrease in credibility such as experiences of attractiveness, graphical (aesthetic) qualities, oddness, etc. (Figure 15, right).

**Summary: simplification (iconization)**

There is reason to believe that well-designed cartoonish simplification (iconization) can have positive qualities in the representation of embodied pedagogical characters. It may ease subjective identification by using generalized, symbolic features. Another aspect is that there are less visual obstacles for subjective identification.[5] This may also be used to more specifically defuse visual clues of ethnicity and gender in order to decrease detrimental prejudices.

A more technically oriented argument for visually simplified characters is that it may decrease the mismatch between highly naturalistic characters as to visual

[5] Thanks to Henrik Enquist (Certec, Lund University) for this alternative view.

appearance (static visual characteristics) and stiff, awkward as well as resource demanding animations. In less naturalistic settings, the degrees of freedom for animation are substantial higher as long as the visual experience functions as a whole. All in all, I find it a bit distressing and a misuse of resources that such a large part of the research field of embodied pedagogical agents seem so stuck to the idea of all-over 'realism'.

## Visual Stereotypes and Embodied Pedagogical Agents

As already argued for, the visual perception of other people plays a central role in human-human social interaction with profound effects on attitudes as well as behaviour. Accordingly, different visual aspects can be assumed to be critical for a smooth and effective human-agent communication and the potential to engage and motivate a learner.

In order to pursue the examination of these issues, it can be fruitful to change the perspective to that of *visual stereotypes* in relation to embodied pedagogical agents. This approach can be used to especially address the questions of to what degree and in what circumstances visual issues have a pedagogical impact regarding embodied pedagogical agents.

### Visual characteristics

In order to approach visual stereotypes in relation to visual properties in embodied pedagogical agents, one can rely on the basic categorizing of visual aspects into dynamic and static characteristics as outlined in the proposition for a graphical design space for embodied pedagogical agents (Chapter 6).

- *i) Dynamic visual characteristics* such as facial expressions and gaze, gestures, and movements.
- *ii) Static visual characteristics* such as body and face properties, skin, hair, clothes and attributes (i.e. the underlying graphical entities).

In the following discussion, the focus is on the static visual properties as a source for the construction of visual stereotypes. The reason for this is that the dynamic qualities (as mentioned previously), are relatively well researched. This is also the case for the non-academic practice of animation, as exemplified in the unofficial canon *The Illusion of Life: Disney Animation* by Frank Thomas and Ollie Johnston (1984), two then leading Disney animators. The explicit articulation of the book is on the art of animation and illusion of life (*dynamic aspects*) while issues of the underlying visual form (*static aspects*) only are addressed implicitly – even if their importance certainly are acknowledged (*Paper I: Gulz & Haake, 2006a*).

## Cognitive implications of visual stereotypes


**Figure 16.** Examples of visual stereotypes

Figure 16 presents four examples of visual stereotypes. Many observers will see in these pictures: (1a) a teenager, (1b) a housewife, (1c) a craftsman, and (1d) an air hostess. A visual stereotype, in our sense of the term, will then consists of a number of static visual attributes in a person that will make a majority of observers perceive the person as an illustration, or a typical instance, of a human group, a professional group, or a social group. In this way, the visual input activates expectations of other aspects of the person: how s/he is likely to behave and to talk, what s/he can be expected to say or not say, what attitudes and opinions s/he will be likely to have, and so on. In this way visual cues carry social and cultural baggage.

In the everyday use of the term, stereotypes convey a negative connotation of human behaviour, but it is not that simple. From a cognitive perspective, the use of stereotypes is probably of outermost importance in order to interact with other people. They function as cognitive *short cuts* to make action and life manageable for human beings. Instead of becoming overwhelmed by analyses, thoughts and questions regarding people that we encounter, we make use of their visual appearance to quickly situate them in order to focus on interaction as such (Brewer, 1988; Laurel, 1993). In this way, visual stereotypes frame peoples' expectations, and also support the building of common references for the conversation. In brief, (visual) stereotypes are a navigation tool in a social environment that would otherwise be overwhelmingly complex and demand a practically insurmountable burden of cognitive processing (Smith & Medin, 1981). This was also one of the 'not thought of' (nasty) problems of artificial intelligence as commented by Moravec (see footnote 3 on page 7).

## Virtual Visual Stereotypes

In their seminal book, *The Media Equation*, Reeves & Nass (1996) convincingly demonstrate how social behaviour and strategies from the real world often are reproduced in interaction with computers. It has also been shown that these findings apply to the reproduction of real world visual stereotypes in the interaction with virtual characters.

A possible conclusion is then that positive as well as negative aspects of real-life visual stereotypes are reproduced in interactive visual media as cognitive tools for handling a complex social environment together with their problematic normative consequences.

### *Novel possibilities …*

There are novel possibilities introduced by visual stereotypes in virtual pedagogical agents. Elaborating on the possibility to break with, or exploit, (visual) stereotypes for pedagogical purposes, an interesting opportunity is to enable the exploration of a broad range of identities and to extend possibilities for social identification and role modelling.

### *… and risks*

As to risks, the construction and promotion of idealized super people with 'perfect' bodies and looks (and even lives) has abounded in non-interactive media such as TV, video and magazines for a long time.

This portrayal of the ideal can be taken one step further with interactive computer media. A key difference lies in what is seen as a central potential of virtual characters – namely their interactivity, relying on autonomous algorithms and models for behaviour, personality, emotions, social strategies and memory. It is not all that inconceivable that the distance between users or learners and those 'ideal super people' will narrow or even diminish. The consequences of such a supposition are certainly not evident – but in an era desperately pursuing perfection in appearance, this might have detrimental effects on people's self-image and self-esteem (Figure 17).


**Figure 17.** The on-line 3D chat *imvu*® (www.imvu.com; © IMVU) explicitly exploits the idea of escaping the reality and one's real self to enter a world of 'perfect' people (with 'perfect' lives).

# *Chapter 9*
# Empirical Findings

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*The empirical findings of this thesis can be found in Paper III-V of the appended papers. The studies behind these three papers are also reported in other papers presenting additional empirical findings. Those papers are also mentioned in this presentation.*

*Furthermore, all studies are the collaborative work of myself, Agneta Gulz (my wife and colleague), and others. Given this, I will in this chapter keep to 'passive tense' and/or 'first person plural'.*

## The Studies

**Paper III:** ***A Look at the Roles of Look & Roles in Embodied Pedagogical Agents – A User Preference Perspective***

*The paper reports on a user study addressing three aspects of embodied pedagogical agents: visual static appearance, pedagogical role, and communicative style. Additional findings from this study are presented in Gulz (2005), Gulz & Haake (2005; 2006b; 2009). (A special thanks to Martin Jonasson for collaboration in the study.)*

### *Study*

In the study, 90 school children (aged 12-15) were (one-by-one) introduced to a dummy multimedia program were they were presented with either an instructor or a learning companion condition. This part of the presentation was communicated by the multimedia program by means of a pre-recorded voice.

The participants were then to make a preference choice between eight visually different embodied pedagogical agents presented on the screen. The eight agents were designed upon four young grown-ups, two males and two females. Their physical appearance was chosen to be relatively neutral.[6] Each person was

[6] The notion "neutral" should here be interpreted as: not visually deviating and/or conspicuous for the participants in the study.

then rendered into either a more naturalistic (detailed & 3D) or a more stylized (simplified & cartoonish) version (see Figure 18).

After the preference choice, the participants were asked whether they preferred a strictly task-oriented or a task- and relation-oriented pedagogical agent.

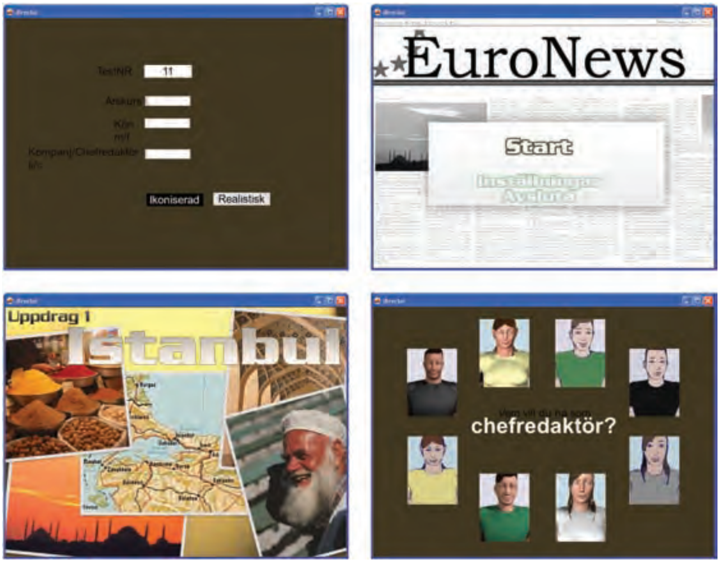


**Figure 18.** The dummy multimedia program used in the study: Top left: data collection of participants and setting for instructor/companion version; Top right: start page, Bottom left: introduction page; Bottom right: Preference choice page.

***Results***

The goal of the study was to explore possible relations between the three aspects mentioned above with respect to user preferences. The results were:

i) when the agent was introduced as a learning companion, female students displayed a significant tendency to choose a more stylized visual character,

ii) when the agent was introduced as a learning companion, female students displayed a significant tendency to choose a task- & relation-oriented agent, and

iii) in the case when students had chosen a more stylized character, there was a significant tendency to choose a task- and relation-oriented agent.

***Comments***

One limitation of the study was that the variables pedagogical role and communicative style of the agents were not implemented as actual algorithm driven agent behaviour. This limitation lowers the ecological value, but may on the other hand capture some additional knowledge on a more generalized, conceptual and articulated level.

Another concern of the study is the age group (12-15 years). Other age groups might have given different results. A personal speculation is that the relative preference for cartoonish stylized agents would increase with younger age groups.

Regarding the results, the most prominent and central finding is that a deconstruction of the user group with respect to parameters such as (in this case) communicative style and gender can give significant results as to specific preferences like pedagogical role and visual style of the agent – a topic that has been discussed earlier in the thesis.

Given the more specific focus of this thesis, the results gave support for the assumption that the graphical style of the embodied pedagogical agent can have significant impact on the experience of the user, and that iconized characters should be considered in cases where subjective identification and social interaction is more emphasized.

**Paper IV: *Visual Femininity and Masculinity in Synthetic Characters & Patterns of Affect***

*The paper reports on a study investigating stereotypical predictions with respect to visual femininity and masculinity in embodied pedagogical agents. (A special thanks to Dan Holmér for collaboration in the study.)*

***Study***

Forty adolescents (aged 13-18) and 40 adults (aged 25-65) participated. In each age group there was an equal number of female and male participants.

In the study, the participants were presented to two computer characters (one female and one male medical doctor) speaking about diurnal rhythm – a topic selected to be relatively gender neutral. The two characters were randomized from a set of two female doctor characters (one more feminine-looking and one more neutral) and two male doctor characters (one more masculine-looking and one more neutral), see Figure 19.

Relevant visual cues were systematically varied, whereas voice, spoken content, linguistic style and role of the characters were held constant. After the session the participants were interviewed about their impressions.

**Figure 19.** Screen shots of the four characters used in the study. Upper left: (more feminine-looking), upper right: (more neutral), lower left: (more neutral), lower right: (more masculine-looking).

***Results***

The results both followed and contradicted stereotype predictions:

i) The two female characters differed in accordance with stereotype predictions (e.g. the more feminine-looking female was perceived as significantly more personal, pleasant, and less intelligent) with the exception of competence-related traits.
ii) The two male characters differed very little with respect to stereotype predictions.
iii) The pattern for male versus female characters was slightly in opposite to stereotype predictions.

***Comments***

The study was inspired by a study reported in Voelker (1994) showing that users of a digital system perceived a more masculine-sounding female voice as more persuasive and intelligent than a corresponding but more feminine-sounding female voice. Our study instead explored whether a parallel pattern of affectively coloured evaluations can be elicited when femininity and masculinity are manipulated via visual cues instead of via voices.

The hypothesis regarding visual stereotype prejudices were correct when comparing the two female characters, whereas there were only small variations between the two male characters.

The interesting, but puzzling result was that no difference in stereotype prejudices were found when comparing the female versus the male characters – this in contradiction to the initial hypothesis.

A possible explanation for the weak or even contradictory results was that gender stereotypes here were overridden by a medical doctor stereotype. In the Swedish society this is a high status profession, with its practitioners ascribed expertise, knowledge and intelligence.

A replication of the study but now with voices only (no visual cues) gave a possible additional explanation. The male voice had a regionally coloured dialect, whereas the female voice was that of standard Swedish. Theory says that dialects are perceived as warmer, kinder, more emotional and more naïve, whereas the official standard version of a language is associated with high status, authority, professionalism, and credibility. Thus, the original experimental setup featured a high-status female voice associated with stereotypic male traits versus a low-status male voice associated stereotypic female traits. In light of this, the 'out-levelled' results in the original study may be due to the fact that dialect and gender stereotypes in this case counteracted one another.

A lesson learned from this study is that different traits in embodied (pedagogical) characters can interact in ways hard to predict.

### Paper V: Challenging Gender Stereotypes using Virtual Pedagogical Characters

*This last paper reports on a study exploring motivational and cognitive effects of more neutral or androgynous-looking versus more feminine-looking and masculine-looking virtual characters. Additional findings from this study are presented in Gulz, Haake & Tärning (2007a; 2007b; 2007c). (Thanks to Adam Altmejd, Aron Vallinder, Betty Tärning and Thérèse Deutgen for collaboration in the study.)*

#### *Study*

158 students, aged 17-19, encountered one out of four virtual presenters informing about university programmes at Lund University (Figure 20).


**Figure 20.** Screenshot from the multimedia presentation with the more androgynous or neutral young woman (FA) presenting the programme in computer engineering at Lund University.

The virtual presenters were visually manipulated to represent gender stereotypicality versus androgyny as follows: a more feminine-looking female character (FF), a more neutral or androgynous-looking female character (FA), a more neutral or androgynous-looking male character (MA), and a more masculine-looking male character (MM), see Figure 21.

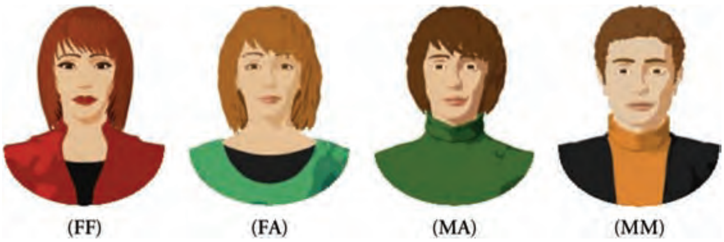


**Figure 21.** The four virtual presenters used in the study.

The two more neutral or androgynous-looking characters (FA & MA) were developed out of an identical bust (3D mesh). Compared to MA, FA had: (i) longer hair, (ii) more regular and slightly plucked eye brows, (iii) different neutral clothing, (iv) painted eye lashes, and (v) a slightly lighter colour scheme.

All other variables were kept constant except the voice (a recording of a female voice), which was digitalized into a female and a male voice.

An important part of the study examined whether the different virtual presenters had any effect on the participating students' attitude to a university programme in computer engineering. The attitudes were measured before and after the multimedia presentation. The relative difference in attitude was denoted the presenters' *implicit* influence.

After this, the students' *explicit* attitudes towards the different virtual characters were measured by means of preference ranking and verbal articulation.

***Results***

All in all, there are several reports from the study (see above), and the focus group interviews are still waiting to be reported. Below follows a summary of the findings presented in *Paper V*.

i) The two more neutral or androgynous-looking characters were generally preferred as presenters when ranked explicitly, in particular so among female participants.

ii) In explicit gender related arguments, FA was (without exception) promoted as presenter in terms of being a woman, whereas FF was generally dismissed for being a woman ('this kind of woman').

iii) Explicit comments of attractiveness and plainness were evenly distributed over the four characters (with the exception of FF who received one third of the attractiveness/non-attractiveness comments). Notably, the students diverged considerable in their opinions regarding the four characters.

iv) The implicit influence of the presenters was measured (as described above) as the relative change in attitude towards the presented education. For female students, the positive implicit influence was evenly distributed over the characters (which can be contrasted to their strong explicit preference for FA & MA). For male students it was MM & FF that had a strong implicit influence, whereas it was FA & MA that were preferred in their explicit ranking and reasoning. That is, there was a considerable mismatch between the implicit and explicit preferences.

***Comments***

Two central results of this study were: (i) that 'more androgynous' characters indeed were possible to use as virtual presenters, and (ii) that there was a considerable mismatch between the students *explicit* (conscious) preferences and argumentation versus the *implicit* (unconscious) impact of the characters, and especially so for the male students.

The virtual characters that presented a university programme in computer engineering can probably be used to also present other educational domains. They may be of particular interest when dealing with gendered occupational choices.

At the same time one should be aware of mismatches between explicit actions and implicit reactions. Androgyny, role modelling, and cultural images are complex phenomena and must be handled with cautious reflection.

## A Comment on Methodology

Methodology is a delicate subject to which whole dissertations can be devoted. With our cross-scientific approach, we pick up methods from quite different academic areas and traditions and have little understanding for the sometimes infected dispute on qualitative versus quantitative methods. Our research projects usually start with an idea or fascination related to some phenomenon. Next step is to formulate some research question – and out from this, hypotheses and methods emerge depending on the phenomenon of interest and the context at hand. With regard to the research questions we are usually dealing with, we employ a mix of qualitative and quantitative methods and aim at measuring both explicit (conscious) actions and implicit (unconscious) reactions (c.f. *Paper V*).

A drawback with this approach is that we do not have specialist expertise in the methods (methodologies) we use. This also means that we, especially with regard to quantitative data collection and data analysis, usually rely on relatively simple and robust experimental designs that require larger data sets (i.e. more test participants). It takes more work, but the quality of the results may even be better.

Finally, as a comment on the eternal disputes on methodology and different scientific approaches and traditions, we propose that the basic and common practice of science (except a creative brain) can be formulated as follows:

i) be as careful and precise as possible during the research process, and
ii) document and report as much as possible of the research process in a clear, transparent, and sincere manner.

In this way, other researchers as well as the surrounding society can evaluate the research and even form different opinions based on the documentation of the research process, the data, and the results. Any critique will then (hopefully) concern the specific study, not a general method.

After all – research is about gaining knowledge of phenomena around us, and in this endeavour methods can be of outmost importance, but in the end they are ... only methods.

# *Chapter 10*
# Discussion

*In this final discussion I comment on the central topics of this thesis and eventually end with a reflection.*

## A General Discussion

The discussions in this thesis have addressed psychological, cognitive and social aspects of embodied virtual characters in pedagogical contexts with respect to static visual characteristics. The virtual characters themselves are, however, computational algorithms and the research area is heavily computational. This makes the study of human–agent interaction a both fascinating and delicate cross-scientific venture. If one aims at more than retrospective descriptive analyses, it is necessary to encompass scientific traditions, methods and skill from many different academic domains – including technology and computation.

### Embodiment

The concept of embodiment is a prerequisite for this thesis. With the breakthrough of embodiment, a whole new spectrum of visually grounded communication strategies was at hand. As we have seen, humans intuitively make use of inter-human social communicative strategies. This anthropomorphic reflex is unconscious and probably biologically hardwired. An argument for this is the view of a by evolution tuned human social intelligence, relying on a whole set of advanced and complex strategies to communicate and navigate in a social world.

This close connection between anthropomorphized human–agent interaction and everyday human–human interaction brings with it the whole baggage of social strategies in the form of stereotypes, prejudices, identification, role modelling, etc. – with all its potentials and risks.

### Virtual embodied characters as a research tool

The visual nature of embodiment sets the focus on the visual characteristics of the communication between human and agent as well as between humans. Virtual embodied characters have a large potential in providing knowledge about human cognition and behaviour. In contrast to real human beings, they can be precisely controlled in interactive experimental settings. For example, it is now possible to examine stereotypes of visual clues, body language, and voice by letting (human) participants encounter the one and same interactive embodied character – with relevant variables (clothes, hair cut, body language, voice) systematically manipulated. This has not been possible before, since not even trained actors exactly can repeat or modify their behaviour, body language, or voice between test rounds.

As for a future research agenda – here I have more than I bargained for.

## The Visual Impact and Pedagogical Implications

Compared to other aspects of embodied pedagogical agents, static visual characteristics are sparsely researched. As for today, we have little knowledge of the impact of visual parameters in pedagogical settings. A glance at other visual media such as theatre, film, and computer games with their strong emphasises on visual aspects makes it on the other hand a both interesting and urgent question.

In an attempt to advocate the static visual qualities, I have in this thesis proposed a framework for a visual (graphical) design space in order to describe what visual properties are actually measured and manipulated in different studies. A future goal is to use this framework to review the research on embodied pedagogical characters. As for now, I have in the thesis commented on the conceptual chaos in the use of 'realism'.

### Simplification (iconization)

Visual simplification (or iconization) has been a central topic in this thesis. With regard to the computational dominance of this field, its rationalistic tradition, and the aim of artificial intelligence to construct an artificial intellect mimicking human cognition, it seems as if 'human naturalism' is an inherent implicit goal of the field per se.

An alternative standpoint is to focus on the development of engaging, effective and smooth interactive embodied pedagogical agents that works in real pedagogical contexts. After all, the main objective for embodied pedagogical agents is to engage in social interaction with learners in order to strengthen the social and communicative features of pedagogical systems.

In the light of this, visually simplified, more or less cartoonish representations of embodied pedagogical characters may have considerable potentials with their possibility to afford subjective identification and thus engagement and motivation. Simplified characters may have similar effects with regard to role modelling and group identification in terms of gender, age, social status, ethnicity, etc.

## Virtual Stereotypes

Regarding the 'social baggage' of embodiment mentioned above, this thesis has looked closer on stereotypes. Simultaneously as virtual characters have the potential to counter stereotypes, the general trend seems to rather be a further exploitation. A troublesome aspect here is that virtual characters do not have the same constraints as to behaviour and visual appearance as humans do. They can – maybe not now, but in the future – be modelled into a sort of magnificent, wonderful super beings with perfect lives. This is nothing new – society has since long created heroes and more lately movie stars and rock stars, but whereas these 'traditional' superstars were imaginary products, these new virtual characters has the power of dynamic interactivity, blurring the border between reality and fantasy.

## Closing

To finally end this thesis, I put forth two reminders and one strange reflection.

***Reminder 1***

Embodied pedagogical agents are no a digital monsters threatening to replace teachers – they are only a tool with the potential to help teachers in daily classroom activities. Nothing can replace a good human teacher, but we will never have enough teachers for our youths – and here they can be a valuable complement.

***Reminder 2***

I surely can get carried away by the possibilities of virtual characters, but in much they are more of an artifact of the future than of today's reality. Creating an artificial being with the social and communicative capabilities of a human is, I believe, far beyond the horizon. In the near future we will probably have to rely more on the human capacity and willingness to engage in virtual creatures, than on the capacity of these creatures.

**A strange reflection**

I have sometimes wondered over the shortcomings of artificial intelligence when it comes to modelling human cognition in its broad sense with emotions, intuition, and social and communicative abilities. On the other hand – are humans that fantastic? If we take a closer look at any human, she or he is so full of strange behaviours, daily mistakes and slips, ambiguous emotions, cognitive breakdowns, incomprehensible utterances, contradictory thoughts, etc.

Considering this: 'Why do we demand so much of these virtual characters? Why do we want them to be so perfect?'

This is to compare apples to oranges. Maybe it is the capacity to communicate and engage in social activity, in spite of all strange and inconsistent events that constantly surround us, that constitutes the human. And the quest for a computational perfect being is in much the ghost of rationality.

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