# Conceptual Design Scheme for Virtual Characters

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**Abstract.** The aim of this paper is to describe some theoretical considerations about virtual character design. In recent years, many prototypes of cognitive and behavioral architectures have been developed to simulate human behavior in artificial agents. Analyzing recent studies, we assume that there exists a variety of computational models and methods in order to increase the cognitive abilities of the virtual characters. In our opinion, it is necessary to perform a synthesis of these approaches in order to improve the existing models and avoiding the application of new approaches. Considering these aspects, in this paper we describe a taxonomy that explores the principal cognitive and computational parameters involved in the design, development and evaluation of a virtual character.

**Keywords:** Virtual characters, Emotions, Gestures, Artificial behavior, Cognitive Modelling.

## 1 Introduction

It is well known that nonverbal communication like emotions, gestures and body movements play an essential role in human communication. Consequently, we have seen an increase in interest in the design and realization of software and hardware systems able to simulate human abilities, e.g. for human-machine interaction such as multimodal interaction, interactive models, virtual reality and 3D interaction [1]. The high rate of evolution of virtual characters applications implies that it is necessary to manage more efficiently the design and development of complex and dynamic behavior. Much research [2] has shown that virtual characters' expressions of empathic emotions enhance users' satisfaction, engagement, perception of the virtual agents, and performance in task achievement [3, 4, 5].

In order to increase reliability, recent studies have proposed a new class of interpolation algorithm for generating facial expressions to manage emotion intensity [6]. MPEG-4 is a standard for facial animation [7, 8, 9] which researchers use to specify both archetypal facial expressions and facial expressions of intermediate emotions [10]. Experiments were conducted to study individual differences in users' perceptions of blended emotions from virtual characters expressions [11, 12]. Layered

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models were defined for relating facial expressions of emotions on the one hand, and, on the other, moods and personality traits, using three different timescales [13]. All of the studies show the existence of different computational models of emotions. Often, the research describes the design and implementation of a complete new prototype, mixing discussion of technical innovations with new application areas or approaches and interaction techniques. In spite of the fact that most of these studies are generic, there is no well-defined and commonly accepted approach regarding how the virtual characters architecture should be designed. Moreover, experimental results show that researchers have designed excellent models of virtual character behavior. Virtual characters are not designed just for movies and games. They can be used for a variety of purposes such as training, education, psychological therapy, etc. For example, eLearning is one application field for virtual characters. They are used to present educational material, answer users' questions and give feedback about learning progression. In general, the virtual characters applications are a topic of interest for many researchers. It is now necessary to identify specific guidelines in order to develop virtual characters able to exhibit more complex behavior.

In this paper, we propose a taxonomy in order to identify the principal cognitive functions involved in the design and evaluation of virtual characters. In many cases, these models are not the result of flawed research, but the necessary negotiation made in the exploration of new approaches that integrate different research areas. So, these approaches allow the implementation of a good system, but the evaluation process is different in comparison to another approach. We want to define the state of the art involved in the design and implementation of virtual characters. We propose an attempt at a taxonomy which describes the principal research for the modelling, realization and evaluation of virtual characters. The paper provides an account of the following problems: 1) virtual character properties; 2) psychological aspects that influence the perception of the virtual character's actions; 3) definition of a virtual character criteria set in order to design successful virtual characters.

The paper consists of seven sections. In the next section, we offer a description of the relation between emotions and virtual characters. The artificial emotions recognition process is discussed in section 3. Gestural behavior is examined in section 4. Section 5 describes the taxonomy for virtual character research. Finally, in section 6 we then offer some conclusions and seek to trace some future directions in virtual characters design.

## 2 Emotions and Virtual Characters

"Emotion researchers define an emotion as a short-lived, biologically based partner of perception, experience, physiology, and communication that occurs in response to specific physical and social challenges and opportunities" [14]. The aim of this definition is to distinguish the emotions from other phenomena. In general, emotions are evoked by flexible interpretations of stimuli and have specific intentional objects while moods have less specific cause and remain for longer periods of time. For example, emotion traits, such as hostility and shyness, respond emotionally to broad classes of stimuli. Mood represents the overall view of an individual internal state. Whereas the emotions are associated with a specific expression or cause, moods are

not identifiable in terms of cause. The difference between emotion and mood is that, emotions regulate actions, while moods modulate the cognition.

Emotion researchers agree on the adaptive functions of emotions, but they propose different explanations for this aspect. The ability to communicate emotions is essential for a natural interaction between human and virtual characters. If a virtual character does not possess emotional expressions, it could be interpreted as indifferent towards the human. Therefore, it is important that a virtual character show its emotional state in order to improve the interaction with the user or with other virtual agents. Specifically, the researcher proposes different approaches and methodologies to design artificial emotions. The aim of this research is to implement, in virtual characters, artificial emotions able to generate affective behavior improving autonomy, adaptation, and social interaction in the virtual environment. Based on the functional role of emotions, [15] specifies 12 potential roles for emotions in artificial systems. A survey of relevant virtual character behavior is showed by [16].

The creation of virtual characters is an interdisciplinary research field. The disciplines involved include design and implementation of cognitive architecture [17], modelling of a nonverbal communication system [18], expressiveness of the virtual character to improve visual realism and to solicit a realistic response [19], and finally to design user-friendly Graphical User Interfaces (GUI) [20]. Other aspects concern behavioral analysis [21] and the realization of the virtual scenario where the virtual characters are posted in [22]. Designing expressive virtual characters raises several research questions [23]. From a computer science point of view, the characters should be able to display facial expressions of complex emotions in real-time based on different user inputs, whilst, from a psychological point of view, designers of virtual characters need to know the cognitive processes regarding user perception and which are involved both in the facial recognition and in the movement expression.

In recent years, several virtual character cognitive architectures have been proposed. The aim of these architectures is to reproduce realistic human abilities, with the purpose of going beyond the display of individual basic emotions models, defined for the facial display through so-called blends of emotion or nonarchetypal expressions [12, 24, 25]. However, applied models and methods, even if derived from an interdisciplinary approach, show some limits. Often the design and implementation of virtual characters is based on specific application requirements or developed as a test to verify a research hypothesis. Such approaches do not always reflect the goals of this research area in terms of qualities of the results to achieve. However, the realizations of virtual characters that show human abilities is a highly complex task. De facto, the research methods used are much discussed.

The major difficulty in this research field is the fact that believability of the virtual characters is essential for an effective interaction. Believability is the ability of the agent to be viewed as a living, although fictional, character. These studies can be divided into two separate but interconnected approaches, which use empirical results to design virtual characters. The first approach creates virtual characters without an internal mental state. In this case, the emotions are the results of mathematical and geometrical models that manage the visual movement of the virtual characters. Research results of this approach are used to build character's animations. The analyses are based on the recognition of emotion by subjects [26, 27]. The second approach designs and develops virtual characters to be included within immersive virtual

environments. The primary goal of this approach is to improve interaction and communication between agents and users. In this case, the computational model of the virtual characters includes a mental state of the personality in order to obtain a more realistic behavior. The purpose of these studies is to measure the communication between subject and virtual characters, such as interaction and collaboration. Compared to the first approach, which simulates all basic emotions, the latter simulates few emotional expressions, but the virtual characters are provided with body movements in order to increase the complexity of the realized actions.

## 3 Modelling Artificial Emotions and Its Recognition

Research results from several fields such as cognitive psychology, social psychology, biomechanics studies on the movements and neuroscience, allow us to define a criteria set framework for the design of virtual characters able to realize realistic behavior [21, 22]. Empirical evidence shows that behavioural expressivity is connected to nonverbal communication, which is generally taken to be indicative of the true psychological state of a virtual character especially when the cues are negative [23, 27]. In the communication process, a smile or another face movement can have different meanings.

The reason for implementing artificial emotions in virtual characters is twofold: one is to generate realistic virtual characters e.g. to support Human-Computer Interaction (HCI) applications, the other is to investigate their recognition processes. For example, research results show that human subjects are able to recognize the artificial emotions realized using the Facial Action Coding System (FACS) developed by [24], which measure facial expressions by Action Units (AU). Each AU allows us to measure how few changes of the face involve more facial muscles. [24] have calculated 44 AUs that realize facial expression changes and 14 AUs that describe grossly the changes in the direction of the look and in the orientation of the head. When AUs occur in combination, they may be additive, in which the combination does not change the appearance of the constituent AU, or non-additive, in which the appearance of the constituents does change. Ekman has observed more than 7,000 combinations from which he derived specific combinations of FACS Action Units representing prototypic expressions of emotion like joy, sadness, anger, disgust, fear, and surprise. Currently, FACS is recognized as a reference system enabling the codification all kinds of facials expressions.

Inspired by FACS, the MPEG-4 standard is particularly important for facial animation. The Facial Definition Parameters set (FDPs) and the Facial Animation Parameter set (FAP) were designed to allow the definition of facial shape and texture, as well as the animation of faces reproducing expressions, emotions and speech pronunciation. FDPs are used to customize a given face model for a particular face. The FDP set contains a 3D mesh (with texture coordinates if texture is used), 3D feature points, and optional texture and other characteristics such as hair, glasses, age and gender.

The FAPs, on the other hand, are based on the study of minimal facial actions and are closely related to muscle actions [28]. They represent a complete set of basic facial actions, such as squeeze or raise eyebrows, open or close eyelids, and therefore allow the representation of most natural facial expressions. All FAPs involving

translational movement are expressed in terms of the Facial Animation Parameter Units (FAPU). FAPUs aim at allowing interpretation of FAPs on any facial model in a consistent way, producing reasonable results in terms of expression and speech pronunciation. "For example, the MPEG-4-based facial animation engine for animating 3D facial models works in real time and is capable of displaying a variety of facial expressions, including speech pronunciation with the help of 66 low-level Facial Animation Parameters" [28, p. 91].

By contrast, the development of automated systems able to comprehend human emotions is more complicated. The reasons are manifold, and some of these can be summarised as follows:

1. The capabilities for modelling characters are limited. Experimental results show the difficulties in modelling the psychological state of a virtual character and to map it to the expression of the corresponding emotion. Other results indicate that subjects perceive characters purely on the basis of their visual appearance or enhanced capabilities.

2. Body expression and emotion perception have a high cognitive value. Face and body both contribute in conveying the emotional state of the individual. In our natural environment, face and body are part of an integrated whole. This correlation is problematic during the modelling of virtual character behavior. Experimental results suggest that if the parametric model of a body posture is not associated with the emotion expression, participants are not able to interpret the behavior of virtual characters.

3. Integration of facial expression and emotional body language is not present or very poor. Electrophysiological correlates indicate that this integration of affective information already takes place at the very earliest stage of face processing. Recognition of the emotion conveyed by the face is systematically influenced by the emotion expressed by the body. When observers have to make judgments about a facial expression, their perception is biased toward the emotional expression conveyed by the body. [29] have shown that "our behavioral and electrophysiological results suggest that when observers view a face in a natural body context, a rapid (<120 ms) automatic evaluation takes place whether the affective information conveyed by face and body are in agreement with each other. This early 'categorization' into congruent and incongruent face-body compounds requires fast visual processing of the emotion expressed by face and body and the rapid integration of meaningful information" [p. 16522].

Another problem linked to emotion recognition concerns facial expression simulation. Empirical results have manifested some problems:

1. Intensity of emotion and emotional decay, a relation that influences the recognition of neutral behavior.

2. Models of emotions. Preliminary studies on facial expression of emotion have supported the universality hypothesis, demonstrating that people of different cultures can display similar expressions in response to similar stimuli; for more details see [24]. An earlier approach to studying emotions, however, came up with the idea that specific emotions are understood in terms of scripts. This view is in opposition to the idea that emotions are universally and easily recognized from facial expressions. However, the FACS is a comprehensive and widely used method of objectively describing facial activity.

3. Computer animation uses different methods to create realistic animations of emotional characters. In particular, these applications are important in the HCI field,

to create life-like synthetic characters. The limits of this field concern the realistic behavior of emotion expression.

In any case, the great advantage of FACS is that all possible facial changes can be recorded and catalogued. Different realistic three-dimensional virtual characters have been developed based on FACS. The FACS allows the creation of stimuli using the combination of different AUs. In past years, different systems have been realized in order to automate emotion recognition. In particular, two general approaches exist: "Feature-point systems track the locations of various landmarks on the face (e.g., pupils, nostrils). The feature vectors of such systems are computed as a function of the positions and relative distances between the points. Appearance based systems, on the other hand, process color information of face patches to form their feature vectors" [30, p.xx]. Most other approaches to automated facial expression analysis so far attempt to recognize a small set of prototypic emotional expressions (for more details see [31]). According to [30], one of the most successful approaches to expression recognition is the Gabor filters method that extracts features and use a vector machine in order to classify the expressions into AU.

## 4 Multifunctional Aspects of the Gestural Behavior

Emotion is a crucial element in any virtual experience: virtual characters that are able to display emotions are more likely to be able to invoke an emotional reaction in the user and thus add to the user's experience. Virtual characters are an important part of the content in many applications such as entertainment, games, story-telling, training environments, virtual therapy, and expressive interactive agents. There are a variety of tools that can either capture or model human behavior. However, the use of these tools is very labour intensive and it is only economical when a very specific performance is required, such as in the movie industry. When we have the necessity to use an interactive system, we have to design virtual characters that include complex behavioral aspects. The modelling of complex behaviour becomes important, because people expect virtual characters to show realistic movements. The aim is to improve communication and socialization within virtual environments between users and virtual characters.

[32] has used meaningful postures in life-size virtual characters in order to investigate the role of posture in the communication through? Interaction with final users. The results indicate that emotional postures designed to portray anger and sad expressions do not play an important role in the way participants respond to interactive virtual characters. It follows that it is better to utilize no postural cues as opposed to using incorrect postural ones. Also, this result depends on different factors, such as the personality of each subject and tendency to attribute a mental state to a virtual character.

Gestures are another important aspect of the interaction between virtual characters and humans. People of all cultures and backgrounds gesticulate when they speak. Hand movements are a natural and pervasive means adding to verbal communication. Researchers from many fields such as psychology, linguistics and neuroscience, have claimed that the two modalities form an integrated system of meaning during language production and comprehension [33, 34].

[33], focusing on language production, was the first to argue that gesture and speech make up a single, integrated system of meaning expression. He assumed that because gesture and speech temporally overlap but convey information in two very different ways - speech is conventionalized and arbitrary, whereas gesture is idiosyncratic and imagistic - the two modalities capture and reflect different aspects of a unitary underlying cognitive process. Thus, according to [33], gesture and speech combine to reveal meaning that is not fully captured in one modality alone. There are two elements of the speech-gesture relationship that are particularly interesting and require further explanation. A crucial aspect of co-speech gestures is tight temporal synchrony with the accompanying speech. In particular, co-speech gestures do not make sense without the accompanying speech, and so it is very important to study gestures in the context of the accompanying speech, that is, to study them as a combined system, not as two separate things.

It is now well established in behavioral studies in psychology that gesture and speech have an integrated relationship in language production [34] and language comprehension. To sum up roughly, these studies have shown that producing and comprehending speech is significantly influenced by the presence of co-speech gestures. Children are also sensitive to gesture in contexts of mathematical reasoning and learning [34, 35, 36].

From discovery of mirror neurons [37], several papers have demonstrated that the human brain, specifically Broca's area, also has similar "mirror properties" (for a review, see [38]). This suggests a link between neural areas responsible for hand actions and language. This linkage between language and action areas of the brain has been fleshed out by a number of recent experiments with humans using different types of cognitive neuroscience methods (for a good recent review, see [39]). Indeed, several studies have found that brain regions that process speech also process actions made with the hand. In addition, evidence from research using Transcranial Magnetic Stimulation (TMS, which interferes with or enhances the neural processing of stimuli) demonstrates that when there is damage to parts of the cerebral cortex that control hand movements, speech comprehension also suffers [37, 38]. As a different test of whether gesture and speech form an integrated system, researchers have used Event-Related Potentials (ERPs, measuring the brain's electrical response to stimuli) to explore the online processing (i.e. the immediate integration) of gesture and speech during language comprehension [40].

Together, these studies from the field of cognitive neuroscience complement the work from psychology showing that gesture influences the behavioral processing of speech during language production and comprehension, and one explanation for this behavioral finding is that gesture and speech are integrated in space and time in the brain's processing of this information.

## 5 Scheme for Virtual Character Research

In this section, we describe the taxonomy realized in order to perform a synthesis of the major aspects involved in virtual character design. The main objective of the taxonomy is to describe the principal cognitive functions that are involved in the design, development and evaluation of virtual characters. Thanks to this scheme, it is possible

to identify both computational and cognitive aspects of the virtual characters research. Our goal is to identify which aspects influence the perception of virtual character behavior while interacting with a human. In the last decade, many virtual character prototypes have been developed, but hardly any uses a full integration of the existing approaches.

For the time being, some questions remain open: how to use the research results in order to improve the realization of the realistic virtual characters? How to avoid the creation of new models, but to improve those extant? In our opinion it is necessary to start updating the current state of the art in virtual characters research. For example, cognitive neuroscience studies allow us to investigate the neural mechanism involved while people interact with virtual agents. These experiments show to which extent the virtual character behavior reflects human expectation in terms of believable, realism, ability, etc.

Many other experimental studies focus on single aspects of virtual character behavior (e.g. emotion, gesture, body movements, etc.), avoiding to integrate different abilities in order to design a complex virtual character behavior [39, 40]. Few experimental studies use this approach, reducing the emotions complexity and adding other abilities such as body movements (posture and gestures), facial expression (which include eye, mouth and lip movements). In this case, virtual characters are included in an immersive virtual environment to explore the interaction behavior with humans.

Our taxonomy wishes to improve the conceptual scheme proposed by [41]. The taxonomy is composed of five categories: 1) Psychological state. 2) Verbal and non-verbal communication. 3) Cognitive processing. 4) Virtual environment. 5) Evaluation method. Each category exhibits specific attributes that refer to the virtual character behavior. Categories and attributes represent some aspects that a virtual character should demonstrate in order to realize a believable behavioural pattern. However, this scheme is not sufficient to specify an agent's behavior. It just represents a summary of the principal approaches used in virtual character research. All these categories have a large knowledge base related to human behavior research. The combination of these categories allows to integrate research areas with different knowledge and goals.

In the next subsection are discussed these five categories that we have drawn out analyzing different studies about the virtual characters researchers. In particular, we will provide some details about each category in order to clarify the content of this scheme. The organisation of the taxonomy is modular, but each category does not exclude the other. Our idea is to identify behavioral categories that are functional to design virtual characters. Several studies simulate only a few attributes of these categories. By contrast, it is necessity to work on the integration of more psychological and computational categories in order to realize virtual characters provide with dynamic and complex behavioral patterns [42].

### 5.1 Psychological States - Personality

In order to create virtual characters with psychological state and emotional personality traits it is necessary to concentrate attention on several research topics (see Table1). Personality, emotion, self-motivation, social relationships, and behavioral capabilities are the fundamentals for providing high-level directives for autonomous character architecture [43].

**Table 1.** Description of the Psychological states – personality category

| Attributes | Objectives | Implementation |
|---|---|---|
| Sex | To develop realistic animation of human facial models. | Some models are proposed in order to develop life-like characters [44]. |
| Mental states | To model the internal psychological state of the character, in order to improve interaction. | Some models are developed for the purpose of psychological studies rather than for use in the creation of virtual characters [45]. |
| Empathy | To explore the effects of empathy between virtual characters and subject. | Few models are developed. These models propose a unified inductive modeling system that generates empathy behavior [46]. |
| Emotions | One the most expressive areas of the body is the face because it is the area most closely observed during an interaction. The ability to model the human face and to animate facial expressions is still a challenge in the field of Computer Graphics. | In recent years, many models and approaches have been used in order to create realistic movements. Different studies use the MPEG-4 Face Animation Parameters (FAPs) [47]. |
| Motivations | To design virtual humans implies defining the motivation mechanism, which control the decision-making at each moment in time. | Few models are created, whose aim is to describe a motivational model of action selection in order to realize coherent behavioral plans [48]. |

First, the simulation of the psychological state requires knowing the psychological research of how humans interact with environmental stimuli. Once this has been determined, the question has to be investigated whether there is a computational model allowing design and implementatoion of these aspects. If necessary, new models have to be developed and evaluated to an extent coherent with the desired human personality traits behavior. Currently, the virtual characters psychological state models include some of these aspects. In particular, many studies focus on emotion expressions.

### 5.2 Verbal and Nonverbal Communication

The importance of the relationship between verbal and nonverbal communication is reflected in the number of attributes associated with this category (see Table 2). Face and body movements are a rich source of information about human behavior. The relationship between psychological state and facial expression as well as the association between changes of voice and body expression during communication has been widely studied by many researchers. In particular, body expressions (eye movements, posture, gestures, etc.) influence the recognition of emotions.

**Table 2.** Description of the verbal and non-verbal communication category

| Attributes | Objectives | Implementation |
|---|---|---|
| Language | The main objective of this study is to realize virtual characters able to generate socially appropriate dialogue. With the development of 3D graphics, it is now possible to create Embodied Agents that have the ability to communicate verbally and non verbally. | At present there is a wide variety of applications that use different modalities of interaction. Recent systems allow the association to each phoneme of the corresponding viseme and then the application of coarticulation rules [49]. |
| Body | The purposes of these studies are to improve the level of co-presence, realism and believability experience within the virtual environment. | Few models are developed. Some studies show that observers judging a facial expression are strongly influenced by emotional body language. They collect behavioral data and simultaneously measure electrical event-related potentials (ERP) [29]. |
| Posture | The aim of these studies is to investigate the impact of a character model posture on the communication within the virtual environment. | Several models investigate the role of the posture. Results indicate that subjects attribute psychological states to the behavioral cues displayed by virtual characters [32]. |
| Gesture | Objective of this research is to improve the naturalness of the virtual characters in their non-verbal communication. | Many models explore the role of gestural behavior. Different studies apply new approaches in order to improve gestural communication using procedural animation [50]. |
| Eye movements | The focus of these studies is to create realistic facial animation, improving non-verbal and verbal communication. | In recent years, several models have been developed. Many works have been proposed in order to animate facial muscles with speech or emotion [51]. |

Some expressive body movements reflect certain basic emotions. Experimental results claim that body movements help a person to cope with experiencing an emotion and perhaps it is also possible to recognize the underlying emotions solely through the recognition of the associated body movements. For example, den Stock et al. [42] report on some recent experimental results indicating significant proximity between faces and bodies in fusiform cortex consistent with the finding that fearful bodies activate the face area in middle fusiform cortex and the finding that watching video images of angry hands and angry faces activate largely overlapping brain areas.

### 5.3 Cognitive Processing

The realization of believable virtual characters requires the collaboration of many research areas. This interdisciplinary context is necessary in order to realize virtual

characters able to perceive the stimuli from the environment, to store some information, and to recall specific information.

For example, in computer games the use of virtual characters able to learn a specific task and to evolve their ability for that task can greatly improve the enjoyment and the strategy of the game play. Cognitive processing is an important bridge between virtual characters and their virtual environment (see Table 3).

**Table 3.** Description of the cognitive processing category

| Attributes | Objectives | Implementation |
|---|---|---|
| Multimodal | The effort to create an embodied conversational agent is a challenge that pertains to different multidisciplinary aspects. The objective of these studies s to realize virtual agents able to communicate in multimodal way. | Many studies on social interface emphasize the role of Embodied Conversional Agents (ECAs). ECAs are interface agents that are able to engage a user in real-time, multimodal dialogue, using verbal and nonverbal behaviors [52]. |
| Attention, Perception, Memory, Learning, Decision making | An embodied agent must be capable of simulating different cognitive abilities such as attention, perception, memory and learning in order to improve the multimodal behavior. | Different studies suggest some potential "next steps" towards the creation of virtual autonomous characters that are lifelike, intelligent and convey empathy [53]. |

## 5.4 Virtual Environments

Virtual environments include virtual characters, which interact with the real users. In this context, the unpredictable actions of the user require a highly interactive environment that is not possible to obtain using predefined sequences of behavior (see Table 4). It is necessary to design virtual characters able to generate autonomous behavior.

**Table 4.** Description of the virtual environments category

| Attributes | Objectives | Implementation |
|---|---|---|
| Scenario and interactions | The success of the interactions relies on the ability of the agents to meet the user's expectations, manifesting a coherent and believable set of behaviors. | Few models are developed. The aim of this research is to integrate the virtual characters into the natural virtual environment or scenario [54]. |

Many studies use dynamic simulations to generate the motion of characters, which co-operate in real time with the users' actions. This approach provides an effective way of generating realistic virtual character behavior in a virtual application in which the realism is a very important aspect. Another important aspect is concerned with testing the behavior of a virtual character while interacting with users.

### 5.5 Evaluation Method

The use of different paradigms and tools to design and to develop virtual characters makes it difficult to evaluate and compare the evaluation methods (see Table 5).

**Table 5.** Description of the evaluation method category

| Attributes | Objectives | Implementation |
|---|---|---|
| Usability tests | The objective of these studies is to analyze the appropriateness of the metaphors used in the design of the virtual character in order to obtain ideas and suggestions to improve the simulation. | The proliferation of research and prototypes for different application domains and the multitude of paradigms and tools make it difficult to evaluate embodied agents. It is necessary to define a checklist that shows the usability approach in order to improve evaluation of the virtual agents' [55]. |
| Neuroscience | The aim of this study is to investigate neuronal activation, in particular the amygdala activation, in response to expression of emotions of real and virtual faces. In particular, the aim of the authors was to analyze whether avatar facial expressions are able to elicit amygdala activation similar to images of real people. | Few studies use the neuroscience method in order to investigate how subjects perceive the artificial faces. These studies allow: verification of the effectiveness of artificial agents to elicit neuronal pattern; use of avatars for neuroimaging studies in order to investigate neuronal mechanism; use of it as a flexible agent in training programs and rehabilitation of patients with emotional dysfunctions. This study showed that the human brain could distinguish an avatar from real faces [56]. |

So far, some experiments have used a combination of different research methods (qualitative and quantitative) based, partly, on Nielsen usability guidelines. A few studies use the neuroscience method in order to investigate the cognitive process of human subjects while interacting with virtual characters. This approach allows precise comparison of, the subject's response from different points of view. Other researchers suggest the elaboration of specific guidelines in order to improve the virtual character evaluation process.

## 6 Conclusion

The aim of this paper has been to elaborate a taxonomy in order to identify the behavioral aspects that influence interaction among real humans and virtual characters. One of the challenges of designing virtual characters is the definition of appropriate models, which concern the relation between realistic emotions and the different modalities of behaviour coordination. Our goal was to provide some theoretical aspects about virtual characters, which represent important conditions of interaction with humans. In this paper, we have sought to identify some of the cognitive and computational aspects that each virtual character should have.

The taxonomy introduces some cognitive aspects that most influence virtual character behavior. The next step is to work on the development of tools able to create virtual characters capable of showing a variety of credible behaviors. The correlations between cognitive and computational aspects could provide useful insights for the development of a new generation of virtual characters. Virtual character behavior should appear more spontaneous and unpredictable.

Virtual characters are an important and powerful part of virtual environment content, especially if the virtual worlds require interaction with real users. However, research results show that users interact with virtual characters in different ways. Many people may have a different level of interaction towards virtual characters. For this reason, non-verbal communication is a very important aspect in the creation of believable characters. It is clear that non-verbal communication depends on different factors connected with virtual character applications. For example, in the eLearning context, it is important that a virtual character show social skills, interaction, feedback and others abilities in order to support the student.

To summarize,, we have made evident many aspects involved in the research and design of expressive virtual characters. Many other models and approaches are used in this field. However, all different areas of research are a challenge to researchers that work on designing virtual characters. At the same time, it is necessary to understand whether all of this research can be integrated into a single development platform.

The challenge for the future is to work to integrate more skills in order to realize virtual characters able to co-operate dynamically within their environment. We hope that this taxonomy can stimulate researchers to develop systems not based upon single abilities, but upon their integration.

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