Chapter 22
Believable Characters

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Introduction

The interactive entertainment industry is one of the fastest growing industries in the world. In 1996, the U.S. entertainment software industry reported $2.6 billion in sales revenue, this figure has more than tripled in 2007 yielding $9.5 billion in revenues [1]. In addition, gamers, the target market for interactive entertainment products, are now reaching beyond the traditional 8–34 year old male to include women, Hispanics, and African Americans [2]. This trend has been observed in several markets, including Japan, China, Korea, and India, who has just published their first international AAA title (defined as high quality games with high budget), a 3D third person action game: *Ghajini – The Game* [3].

The topic of believable characters is becoming a central issue when designing and developing games for today's game industry. While narrative and character were considered secondary to game mechanics, games are currently evolving to integrate characters, narrative, and drama as part of their design. One can see this pattern through the emergence of games like *Assassin's Creed* (published by Ubisoft 2008), *Hotel Dusk* (published by Nintendo 2007), and *Prince of Persia series* (published by Ubisoft), which emphasized character and narrative as part of their design.

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Beyond the entertainment industry, the use of virtual environments for learning, health therapy, cultural awareness, and training is increasingly becoming a reality. In the recent years, there has been an increase in the number of research initiatives that use simulations and interactive 3D environments for a wide variety of applications [4–11]. Several great examples are displayed in the projects developed by Institute of Creative Technologies at University of Southern California, where they utilize 3D environments with rich characters to teach cultural norms and foreign language, among other subjects. These applications provide a safe and comfortable environment for participants to interact within and learn at their own pace. In order to achieve their goals, however, such applications require realistic simulation of culture, people, and space. Thus, again the topic of believable characters is gaining more attention as a central topic that deserves further attention.

Since the above mentioned applications are typically interactive, animated believable characters are often required to adapt based on the interaction. Current industry methods, however, rely on heavy scripting, where voice acting, dialogue scripts, hand-coded animation routines, and hard-coded behaviors are used to portray the desired character; To mention a few examples of games that employ very detailed motion-captured characters, readers are referred to *Assassins' Creed* and *Prince of Persia* (developed by Ubisoft) and *Façade* (developed by Mateas and Stern [12]), see Figure 1. In these games, artists work very diligently to detail characters' mannerisms and body motion to exhibit the right character characteristics [3]. Such attention to detail of the non-verbal behaviors is a crucial element for character believability [4].

As one can guess, this kind of scripting is labor intensive and rigid, as it does not adapt to all variations induced by interaction. An alternative is to use artificial intelligent algorithms and graphics techniques to adapt character behaviors to variations in context induced by interaction. This alternative, however, is not as simple as it sounds, as it has been under research for many years and is still an open problem. Researchers have been working on several fronts to create believable expressive characters that can dynamically adapt within interactive narratives. Graphics researchers, for example, explored the integration of emotions and personality as parameters to modify virtual character animations [5–7]. Researchers working on developing conversational agents focus on building articulate virtual characters that can automatically synchronize gesture and speech [8]. Artificial intelligence

Fig. 1 Screenshots from games and interactive media featuring characters

researchers focus on integrating models of emotion and personality to build characters that have the ability to improvise [9–11].

As researchers tackle different aspects of this open problem, gaps between these different directions start to appear. One important gap is the gap between character models or attributes, such as personality, physical appearance, and emotions, and how characters use nonverbal behaviour to portray these attributes. In order for a character to adapt, it needs to not only be able to automatically select its motions and execute its actions, but to also select nonverbal behaviours that convey and maintain its attributes. Let's take a character within a soccer game, for example. Such a character is required to adapt and blend between different actions, such as dribbling, diving, running, walking, scoring, yelling, and arguing with the referee, to mention a few actions. This character should be able to select its actions based on the current context and its own goals. In choosing how to blend between actions and how to execute the animations, it needs to convey and maintain its own personality and emotions. The important open problem here is how to enable characters to do this without hand coding all different variations given all different contexts? This is the central question and problem that this chapter deals with. The aim is to review ongoing research that may provide readers with a good starting point to tackle this problem.

To start discussing this problem, we will first define believability, or believable characters. Believability is gauged by the extent to which a viewer engages and empathizes with an animated character [13–15]. In the context of believability, it is important to note the theory of the Uncanny Valley. Proposed in 1970 by Japanese roboticist Masahiro Mori, the theory explains human reactions towards increasing levels of realism to non-human entities, e.g., robots. The theory suggests that humans may develop feelings of repulsion or negativity towards non-human entities as the level of realism increases. In recent years, the application of the Uncanny Valley theory broadened to areas of animation. In the context of this chapter, we look towards believability over realism, focusing on broader concepts of nonverbal communication that may contribute to future efforts to solve the Uncanny Valley problem.

Character believability can be approached from several perspectives, including personality theories, movement theories, emotion and cognitive theories. Each of these perspectives have been studied in different fields of inquiry, including psychology, kinesiology, animation, and acting. This chapter attempts to discuss many of these perspectives. However, due to space limitations several notable works are left out, such as the narrative and literature perspective.

In this chapter we study two concepts: *non-verbal behavior* and their relation to *character attributes*. We define non-verbal behavior as a single or pattern of movements and postures that are exhibited in the body, such as hand movement, or leg movement. For example, the motion of quickly glancing at a character then at the ground is considered a non-verbal behavior pattern. We use the terms character attributes, character characteristics, and character model to mean a list of parameters that define a character, including age, physique, personality, behavior tendencies, quirks, and habits.

We specifically explore believable character through personality models (e.g., Factor theories from psychology [16, 17]), nonverbal character behavior models (e.g., Ekman's Facial experession [18]), motion analysis models (e.g., Laban Movement Analysis [19, 20]), improvisational theatre character models (e.g., Johnstone's impro [21, 22]) and animation techniques, including Disney's animation methods [13]. In discussing these models, we will discuss theories as well as practical applications of these models within the computer science or believable agents field. We will conclude by discussing the current state of the art of interactive believable characters, identifying open problems that need to be addressed in order for the field to move forward.

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Character Personality

The term personality has its origin in the Ancient Greek literature; it comes from the role played by actors who wore a mask and read aloud the script from their characters' scroll. Character as a synonym of personality comes from this same theatrical origin; the word *persona* was used for *mask*. Personality is a psychological concept that has been widely used inside and outside this field. Aiken [23] (page xi) describes that:

> The term personality refers to the organized totality of the qualities, traits, and behaviors that characterize a person's individuality and by which, together with his or her physical attributes, the person is recognized as unique.

This definition reached consensus. However, Aiken [23] also warns that this definition is open and abstract, and hence difficult to operationalize. Different theories define personality with different terms and emphasize certain characteristics on top of others. Nevertheless, all of them agree that uniqueness is a key of personality, and that personality is a combination of variables that composes a unique pattern of behavior.

Personality is an important concept that is related to character believability. Characters seen in movies, theatre productions, animations, and video games all inhabit a particular personality. This personality is what makes them distinct and memorable. We expect characters to have personality and subject such personality through their goals, behaviors, and expressions. But what is personality and how can it be

operationalized for computational representation of an adaptive believable character? In this section, we will look at previous work from psychology and theatre to try to conceptualize an appropriate computational representation. We will also discuss previous computational models of personality within fields such as graphics and artificial intelligence.

Through the literature, two theoretical perspectives of personality are assumed: *nomothetic* and *idiographic*. The *nomothetic* perspective approaches personality from a general perspective trying to compose personality models which can explain all different types of personalities. The *idiographic* perspective emphasizes the uniqueness of personality structure with the belief that every person has his own system, such as in phenomenological theories [24]. In this section, we discuss different personality models that fall within the nomothetic perspective, because we believe this approach is most appropriate for the development of computational models.

Body Type Theories

Theories on body-types have typically collected their data from physiological characteristics and made assumptions based on generalizations. Since there are many exceptions to their classifications, these theories do not enjoy academic popularity, yet they could offer physical cues for modeling characters. Major body-type researchers and theorists were criminologists, such as Cesare Lombroso [25], Ernst Kretschmer [26], and William Sheldon and S. S. Stevens [27].

Lombroso studied the body constitution of criminals. He stated that their physiological development is in a lower stage, and that their physiognomy is different from other people. Lombroso presumed that there was a born-criminal conception; however, since many other criminals don't possess such features, his idea didn't receive much popularity. Repeated identified atavistic characteristics were: large jaws, high cheekbones, receding foreheads, handle-shape ears, long arms, and other primitive physical traits [25].

Ernst Kretschmer [26] created the first scientific theory describing personality types based on body build. However, his research had low validity and applications of it were relegated. He collected different data measuring bodily constitution of mental patients and others, which he used to formulate four categorizations of body types:

1) *Asthenic or Leptosomic* physique: tall, thin, lanky, angular body build. People in this type are characterized as introverts, withdrawing behavior, and 'schizoid temperament'. This type of mental patient has schizophrenic symptoms.
2) *Pyknic* physique: round, stocky body build. People in this type are associated with emotional instability. Mental patients with this body complex develop bipolar disorder (manic-depressive).
3) *Athletic* physique: broad shoulders and slim hips. People in this type are prone to develop either a maniac-depressive disorder or schizophrenia.
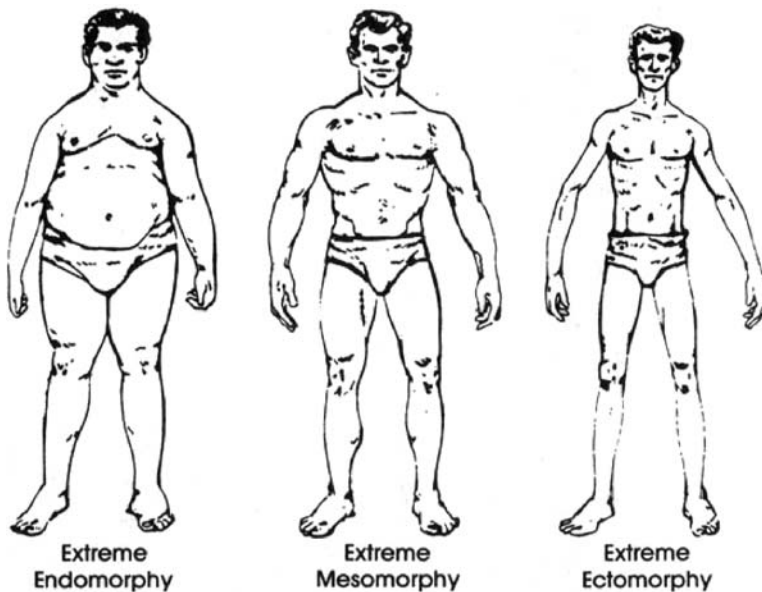
Fig. 2 Sheldom's body types

4) *Dysplastic* physique: any other body build that does not fit into any of the three
   other categories.

Similar to Kretschmer, Sheldon and Stevens [27] developed a quantitative classifi-
cation of personality along three dimensions of body types: *Endomorphy* (fatness),
mesomorphy (muscularity), and *ectomorphy* (thinness), where each dimension was
defined on a score from 1 to 7. For example, a person with 7 for *endomorphy*, 1 for
mesomorphy, and 1 for *ectomorphy* represents an extremely fat person who lacks
other characteristics (see Figure 2). Their classification method is fuzzy as it is hard
to score measures such as fatness or thinness. They found correlations between high
scores of body types to temperament types which also ranged in a 7-point scale. The
temperament types are:

1) *Viscerotonics*: associated to the endomorphy type. This temperament is
   characterized by being gregarious, friendly, and the enjoyment of comfort
   and eating.
2) *Somatotonics*: correlated to the mesomorphy type. This temperament is charac-
   terized by enjoying physical exercise, dominance, being loud and assertive, but
   not empathetic.
3) *Cerebrotonics*: linked to ectomorphy. This temperament is characterized by be-
   ing quiet and reserved, reacting quickly, but over-sensitive to pain and have
   sleeping difficulties.

Body type theories are interesting to explore further for believable characters. They represent an important construct for character designs, concepts, and development. However, we see this type of approach to be in the hand of a designer rather than a decision of an adaptive system. The development of this approach could be a useful tool for designers as they develop their own characters, as well as a method for training character design artists.

Psychodynamic Theories

Freud, known for pioneering the psychoanalysis approach to therapy, developed a theory of personality where each individual was described to have three levels of awareness: unconscious, preconscious and conscious [28]. Personality was then categorized as three entities: id, ego, and superego. The id is full of animal instincts and operates by prioritizing pleasure satisfaction, but is purely unconscious. The ego mediates between the id, the superego, and the external world by evaluating the consequences of actions. The superego is formed by the mandates that have been internalized, and the ideal image of oneself. The ego and superego have unconscious, preconscious, and conscious levels. According to Freud the human personality is a struggle of power among id, ego, and superego.

Freud also asserts that personality is shaped through the progress of the psychosexual stages [23, 29]. During each stage a part of the body is the primary source of satisfaction and psychoenergetical (libidinal) stimulation. The first stage is oral, from birth to eighteen months, in which the mouth brings gratification as in eating and sucking. The second stage is anal, from the eighteen months to three years old, in which the anus provides satisfaction by retaining and defecating, and sphincter control is achieved. The third stage is phallic, from three to six years old, in which genitals are the focus in a rudimentary and egocentric way. The fourth stage is latency, from six to twelve years old, and is characterized by a decrease in the concentration of the genital organs. Finally is the genital stage, from the age of twelve, when genitals are the center of gratification, sexual instincts are fully developed, and sexual maturity is achieved. However, the libidinal energy that flows might get stuck in certain psychosexual stages. This fixation can be the result of traumatic or stressful experiences; it might also lead to regression of behaviors. For instance, fixation in the oral stage could be the cause of verbosity, gorging, smoking, nail biting, sarcasm or hostility. These characteristics originate from gratification of the mouth and lips through sucking, eating, and chewing. Whereas fixation in the anal stage can develop into an obsessive-compulsive personality, stubbornness, stinginess, stuttering, and petulance, having to do with the satisfaction of eliminating and controlling feces.

There are a lot of different theories that emerged based on psycho-analysis. One such research was the work of Carl Jung [29–31]. Jung detached from Freud's work; he analyzed the personality through different ways of orientation towards the external world. He identified two attitudes and four functions of thoughts shown in

Table 1 The components of
Jung's personality types

	Introversion	Extroversion
Rational	Thinking	Thinking
	Feeling	Feeling
Irrational	Sensation	Sensation
	Intuition	Intuition

Table 2 Myers-Briggs Type Indicator Personality Inventory

I	T	N	J
Introversion	Thinking	iNtuition	Judging
Extraversion	Feeling	Sensation	Perceiving
E	F	S	P

Table 1. The attitudes were *extroversion*, which looks towards the outside world, and *introversion*, which leans towards the internal world. The functions were based on the functions of the Ego: Thinking, Feeling, Sensation, and Intuition. *Thinking* and *Feeling* were considered *Rational* functions (where Jung accepts some emotions as Rational and others Irrational), and *Sensation* and *Intuition* were *Irrational*. The Rational and Irrational pairings were considered polar opposites. Jung's theory is of particular importance to us here as it has influenced much of the work in animation and motion analysis theories. These theories and approaches will be discussed below.

Based on his theory, the Myers-Briggs Type-Indicator personality inventory was developed [23, 32]. The Myers-Briggs typology places Introversion and Extraversion alongside the Ego Functions, adding an additional pairing: *Judging* and *Perceiving*. Individuals are typed as having characteristics of, and abilities within all eight functions, yet will exhibit dominant preferences among them.

Personality types according the MBTI are labeled following the letter coding, for example ESTJ (Extraversion-Sensation- Thinking -Judging), shown in Table 2. The main characteristics for each type are as follows:

- I: The interest resides in ideas, and analysis. Internal reasons are the source of motivation, and privacy is appreciated. One-to-one relationships are preferred. Related professions are librarians, anesthesiologists, and accountants.
- E: the environment and interacting with it are the major interests. People with high E are sociable, demonstrative, impulsive, and eager to lead. Linked occupations to this type are travel guides, and actors.
- T: objective observations and logical thinking are prioritized. People are identified as analytical, skeptical, and fair. Professions identified with high Thinking scores are engineers and computer scientists.
- F: values objects, people, and ideas. People with high F are emphatic and altruists. Occupations linked to F are nursing, teaching and religious clerking.
- N: the emphasis is on the upcoming possibilities, the associations that can be generated, and the interpretation of meanings. People with high score on

intuition like complexity and creativity. They are related to academic or artistic professions.

- S: attention to what is actually perceived by the senses, emphasizing the present. This type defines people as realistic, conventional, good observers, attention to and memory for detail, use common sense, dislike complexity, and enjoy the present. Typical professions associated to this type are accountant, banker, and managers.
- J: the interaction with the world is mainly through T or F functions, and having a plan of action. It is associated with rules, obedience and self-control. Occupations related to J are governmental and educational managers.
- P: interaction in the external world is characterized by using N or S functions, adapting as the situations change. It provides the ability to cope with new situations; it is also linked to autonomy and procrastination.

An important aspect of interpreting the sixteen variations is called *Type Dynamics*. One preference will have the strongest influence, and is called the *dominant function*. The second strongest preference is called the *auxiliary function*, which supports and balances the dominant. The *tertiary function* is the function opposite from an individual's auxiliary function, and tends to develop importance later in one's life. The fourth function is called the *inferior function*. It can surface unconsciously when an individual is stressed and one's dominant and auxiliary resources are exhausted. For instance, if the *dominant function* is T (a judgment type) the *auxiliary function* is a perceiving type, like S the *tertiary function* would be N, and the *inferior function* would be F, for the ESTJ type.

Traits Theories

Gordon Allport developed the first personality trait theory [23, 29]. Trait theories surpass the body type theories discussed above. The former introduces a continuum where a personality is defined as a point in the continuum. In contrast, Allport's trait theory defined three different groups of traits:

- *Cardinal traits*: highly present across situations. It is expected that a person only has a few of the following traits: despotism, humanitarianism, power striving, sadism, narcissism.
- *Central traits*: likely present in a range of situations. They are more common than cardinal traits. For example: assertiveness, honesty, gregariousness, trustworthiness.
- *Secondary traits*: related to certain situations, such as food or musical preferences.

Allport's conception of personality [23, 29] stands apart from psychoanalysis, he considered it over-concerned with unconscious mechanisms that manifest as drives. Allport embraced an idiographic approach advocating that personalities are unique, and that they change throughout our lives. Although certain patterns might remain,

motivations during childhood are different from those in adulthood; their functions
are independent since they serve different purposes. Therefore, there is no need to
look into a person's past. He also considered intentions as the shapers of personality.

Factor Theories

Personality factor theories were constructed from statistical analysis. Several factor
theories were proposed. One of the early models was Eysenck's three factor model,
in which the factors were 'super-traits' [23, 29] represented as a bi-dimensional
chart: y-axis representing introversion-extroversion and the x-axis representing
emotional stability-instability (see Figure 3). According to Eysenck, introverts are
quiet, reliable, planners, intellectual rather than social, and tend to have the ability to
control their own emotions. Extraverts, on the other hand, are social, impulsive, and
look for excitement. People with high scores in emotional instability are referred
as neurotics and are anxious, moving constantly, and temperamental, while people
who score high on the emotional stability dimension are calm and mood stable. The
third factor, Psychoticism was added later, and thus does not have a graphical rep-
resentation. It is linked to aggression, impulsivity, and inability to establish rapport.

Based on Eysenck's work, Cattell [23, 33] developed a multifactor theory de-
scribing personality in 16 Factors, which were:
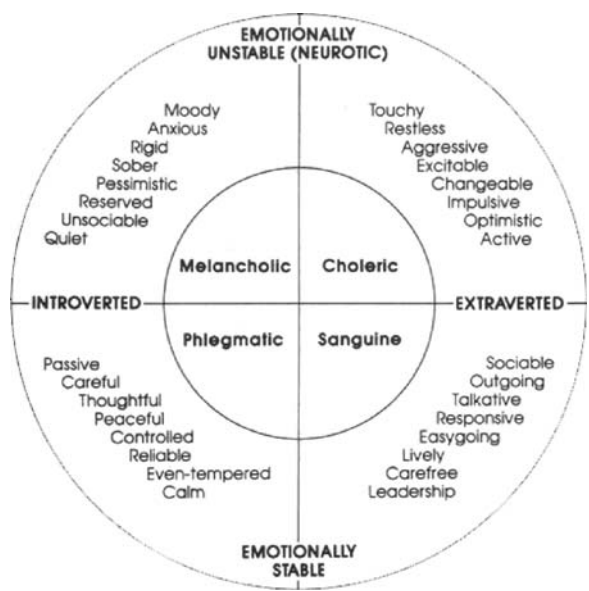
Fig. 3 Eysenck's personality model

- Warmth
- Intellect
- Emotional Stability
- Dominance
- Liveliness
- Rule-Consciousness
- Social Assertiveness
- Sensitivity
- Paranoia
- Abstractedness
- Introversion
- Anxiety
- Open-Mindedness
- Independence
- Perfectionism
- Tension

Several years later, Costa et al. [34] developed the Five Factor Model (also known as FFM, Big Five, or OCEAN) which is one of the most widely accepted personality models as it presents high dimensional consistency in different situations and across cultures [17]. The five factors are: Openness, Consciousness, Extroversion, Agreeableness, and Neuroticism (see Table 3). A personality is then defined as a score in the each factor representing a point in this 5-dimentional space [35].

For computational models, the factor theories are probably the most promising models of all others described in this section so far. They are the easiest to formalize algorithmically. It is to no one's surprise that several agent models have used these theories, as will be discussed later, for creating personality based characters. However, factor theories only examine the character attributes aspect of character representation with little information on how such personalities are manifested

Table 3 Five Factor Model

Dimension	Refers to	If low score
Openness	Imaginative, prefer variety, independent, intellectual sensitive	Down-to-earth, conventional, conforming, low aesthetical appreciation
Conscientiousness	Well-organized, careful, reliable, self-discipline, consistent	Disorganized, careless, weak-willed, aimless
Extraversion	Sociable, warmth, affectionate, optimistic, active	Reserved, sober, retiring
Agreeableness	Trusting, helpful, softhearted, modesty	Suspicious, cynical, ruthless, uncooperative
Neuroticism	Anxiety, experience negative emotions, vulnerability, worrying, impulsiveness	Secure, calm, self-satisfied

through nonverbal behaviors or mannerisms. Thus, most computational models based on factor theories, as we shall see later, fail to truly develop a believable character due to their inability to represent or develop the link between personality and behavior models.

Johnstone's Fast Food Stanislavsky Model

Stanislavisky [36, 37] is a famous Russian director who composed a theory for acting that is currently used by many acting schools to teach actors how to build and develop their characters. In his teachings, he discussed the importance of purpose for a character. Thus, instead of an actor playing an emotion, the actor would develop his actions depending on his character's goals, tactics, and purpose.

Johnstone [21, 22] is a professor emeritus at the University of Calgary and former founding Artistic Director of the Loose Moose Theatre. Johnstone is well known for his training courses on improvisational theatre techniques. In his teachings, he uses several improvisational tools that students can use to start role playing. Johnstone took the Stanislavsky model and developed several exercises (examples are shown in Table 4) defined in terms of purpose. One such exercise of interest is Fast-Food Stanislavsky based on Stanislavsky's model [21, 22].

Johnstone identified several parameters of character representation that can affect non-verbal behaviors. One such parameter is *status*. He identified *status* as a major signifier defining posture, gaze, and use of space in movement. A person of high status, for example, occupies more space, with erect posture, and always looks people in the eye. A person of low status, on the other hand, tends to occupy less space, with more inward posture, hunched back, and always looks away from people. Johnstone stated that characters often identify their status in comparison to other characters in the space, and behave relatively low or high by modifying their posture, gaze, and use of space in opposition to other characters in the space.

These models are indeed interesting to verify in terms of their computational significance. It is also of interest to verify their relation to believability and utility in developing adaptive believable characters. We will discuss two studies related

Table 4 Fast Food Stanislavsky

To Give Someone a Bad Time	To be Thought a 'Computer'
Invade their space.	Be cold and distant.
Be restless, tap fingers.	Be insensitive to pain or pleasure.
Cross your legs away from them.	Dislike physical contact.
Frown; sigh; 'tut'.	Other people are slow.
Glare at them.	Pause before answering.
Laugh at wrong time.	Be efficient – everything in its right place.
Poke them with finger.	

to this idea. The first is a simulation by Harger to show the role of status on body movement (see next section). The second is a study we conducted to verify the use of FFM as a character model and develop a set of nonverbal behaviour patterns that are linked with the different character models defined by Johnstone.

Personality and Believable Characters

Several research projects used the personality models discussed above to develop virtual animated believable characters. In this section we discuss some of these projects. Table 5 summarizes these believable character models and the personality models they used.

André et al. [38] have employed personality as a variable to achieve fine control on affect. They used the Five Factor Model, but only implemented the extraversion and agreeableness dimensions. They created three different environments to try their implementation: *Virtual Puppet Theater*, *Inhabited Market Place*, and *Presence*. *Puppet* is a virtual learning environment specially designed for kids. The setting for this project is in a farmyard, where the user can interact through different modes. He can, through his avatar, interact with the environment and other characters, such as pigs and cows. He can also observe interactions among the autonomous characters representing the animals in the zoo. Alternatively, he can play as a director and set up the story and characters' interactions. The objective of the project is to teach children to recognize how emotions and personalities influence behaviors. *Inhabited* is a virtual market place where personalized agents interact among each other providing information. The scripts were given special attention towards depicting personality. *Presence* is a kiosk application, where users interact with characters to get certain kinds of information. They used believable characters extensively in all these experiences. The goal was to create a more engaging experience through such

Table 5 Computational models for believable characters that embedded personality

Authors	Personality Model	Applications
André et al.	FFM, but only implemented extraversion and agreeableness	*Puppet* – kids as users, to recognize emotions and personalities *Inhabited Market Place* – to improve sales presentation by simulated dialogues
		Presence – kiosk, to improve user interface
Chittaro & Serra	FFM	*Cybertherapy*
Campos et al.	FFM Jung	*SimOrg*
Vick	FFM, 4 dimensions	*Game Space*
Brenda Harger	Johnstone's Status parameter	*This is my Space* simulation

believable characters that exhibit different personalities. While much work has been done on these simulations to represent personality and express it through visual and audio output (through the agents depicted in the simulations), the link between personality and nonverbal behavior are hand coded and thus less formalized.

Chittaro and Serra [39] developed another model for believable characters, where the goal was to create realistic characters that can be used for a psychotherapy application. Although they are aware of the aspects for creating believable characters, they pursued 'realism' without addressing the uncanny valley problem. Like Andre et al., Chittaro and Serra also used the Five Factor model for depicting personality, where each dimension was represented on a scale of 0 to 100. They used probability to model unpredictability; they also used several heuristics to establish a link between the personality type and animation parameters; for example they used neuroticism as a measure of animation speed. Like Andre et al.'s work, Chittaro and Serra did an incredible job representing personality. However, they focused on realism rather than believability. They also derived the link between animation and personality based on best guesses or heuristics approach. This chapter calls for a formal model to derive such a link.

Campos et al. [40] aimed to develop autonomous agents. They used personality as a function that allows each agent to be unique and different from the other. They created a software company simulation, called *SimOrg*, to experiment with the use of personality; developing two different personality models based on the Five Factor model and Jung's model. They collected information describing how different personality models performed on prototypical tasks within a software company. Based on this data, they derived the link between personality and job performance. Although this work presents an interesting model to show job performance and personality, it did not explain or integrate a model of nonverbal behavior as a factor of personality.

Vick [41] developed a testing bed for integrating personality and emotions within game characters. To model personality he used the Five Factor Model. However, he implemented only four dimensions: extraversion, openness, consciousness, and neuroticism. He used a text-based interface to show character behaviors. His simulation showed interesting effects where knowledge, emotional and personality states of one character were refined by other characters. The work deserves more exploration on the use and representation of visual and audio output, via animation and mannerisms.

In addition to this work, Harger proposed a preliminary study that used improvisational theatre models to develop believable characters. Harger is herself an improvisational theatre actor who teaches at the Carnegie Mellon University, Entertainment Technology Center. Her teaching emphasizes the use of improvisational techniques for creating and conceptualizing character models and animation for interactive entertainment. With help from several graduate students at the Entertainment Technology Center, she developed a simple personality simulation where several characters enter a room and say the statement "This is my Space." The users of this simulation have the ability to define characters' personality through one quantitative parameter: status. Through this parameter one can see different ways

that characters can perform the entrance action [42, 43]. This simulation was meant as a proof of concept-an exploration of the use of improvisational techniques as a base for character models. Harger's work is important as it defines personality in terms of behavior and attributes rather than attributes alone.

This section has concentrated on character attributes, but has not addressed behavior in any detail. The topic of behavior is of special importance to the industry as it tries to develop not only character attributes but visual representations of characters. As such industry designers have developed their own approximations of character personalities which rely primarily on how characters are portrayed visually or aurally. Different game designers defined character personalities using a single adjective, not necessarily basing their choices on the psychological models described above, e.g. [44]. These professionals are more influenced by practice and art. For instance, George Broussard discusses personality through how the character reacts to situations. He defines Max Payne's personality, for example, through the way he speaks. Toby Gard, creator of Lara Croft, states that the characters' personality comes from the drawings. A similar declaration was made by Michael Ancel about Rayman, stating that the animations unveiled the personality.

Unfortunately, the industry has not developed any formal techniques or models for developing nonverbal behaviors. Theoretical frameworks that target this area are very few and tend to tackle some isolated parameter, such as facial expressions [18]. Nevertheless, in the next sections, we will discuss these topics in detail outlining some of the most prominent work developed in the area of nonverbal behavior.

Nonverbal Behavior Theory and Models

The topic of nonverbal behaviors received some attention within several disciplines, including psychology, communication, and acting. One of the earliest nonverbal behavior systems was developed by Francios Delsarte. Delsarte was born in France in 1811. He developed a formalized system describing the expressive parameters of motion, which till this day is the best comprehensive work that specifically explores the expressiveness of nonverbal behavior [45, 46]. His nonverbal method has been used to train many famous actors, including Kirk Douglas. The method was very popular during the turn of the century, but then received much criticism caused by misinterpretations of the aim and details of the technique.

An interest in analyzing movement was revived during the Industrial Revolution. During this era, the mechanization of labor influenced a scientific, analytic approach to efficiency in the workplace. The photographic studies of Eadweard Muybridge (1830–1904) gave people a new way to understand human and animal movement. Muybridge's techniques were improved upon by Etienne Jules Marey (1830–1904), who equalized the intervals between photographs, providing an accurate space/time analysis of motion [47].

The field of ergonomics also bloomed during this era, with the work of Frederick Winslow Taylor (1856–1915), followed by Frank (1868–1924) and Lillian Gilbreth

(1878–1972). Taylor developed Scientific Management, and conducted studies that resulted in the standardization of shovel sizes. The Gilbreth's work emphasized eliminating unnecessary steps needed to achieve tasks [47].

During World War II, Rudolph Laban (1879–1958), an established movement theorist and choreographer, collaborated with F. C. Lawrence on ergonomic studies of factory workers. As women worked in factories while male laborers were on the battlefield, they were required to operate machinery designed for men. These studies resulted in the refinement of Laban's Effort theory, which addressed the rhythmic phrasing of movement qualities as a key element of biomechanical functioning that also awakened the pure joy of moving by connecting motivation to movement [19].

These theories led to the development of motion theories that had great influence beyond the area where they were originally applied. For example, Laban's movement models have been applied in areas such as dance, acting, and recently animation. In this section, we look at these theories in more depth. We also discuss their application to believable characters research.

In psychology and linguistics, there has been some work that explored the use of nonverbal behavior as a communication mechanism, exploring its link to emotions, social power and structure, and its relation to speech. Many studies within psychology and sociology relied on observation of human actions. One fundamental issue that comes into play with such observation studies is the measurement and understanding of human actions. In 1978 Harper et al. [48] published a review of notation systems used for this purpose. They first defined non-verbal communication borrowing from Dittman [49] who defined nonverbal communication as:

> The sending person (source), having an idea to get across, transforms his idea in linguistic forms (source encoding); . . . he shapes these linguistic forms by means of his vocal apparatus and articulators into sounds (channel) encoding . . . The receiving person hears the sounds through the air between them (channel) and groups them together into linguistic forms (channel decoding), which he finally translates centrally (user decoding) into the idea the sending person had wished to communicate, thus understanding what was said (user).

They diagram this as:

Source -> source encoder -> channel encoder -> channel -> channel decoder -> user decoder -> user

Looking at this from the point of view of developing a computational theory of communication, there are four important aspects:

 a) The information contained in the message.
 b) The coding process that takes place on both sides.
 c) The channels employed; their capacities and limitations.
 d) The effects of noise on accurate transmission.

One of the main works that Harper et al. [48] focused on in their review is the structural approach adopted by the early pioneer Birdwhistell [50] and the later external variable approach developed by Ekman and others [18].

Structural Approach

Birdwhistell [50] was a linguist, and sought to find in movement studies (*kinesics*) the same basic unit of measurement that exists in linguistics, the *morpheme*. He identifies these as *kinemes*, the smallest set of body movements with the same differential meaning, which are in turn composed of *allokines*, similar to *phonemes*. These last from 1/50 of a second to over 3 seconds. This means that observers need to be able to capture or play the motion in slow-motion to be able to detect such subtle details. Birdwhistell hypothesizes that there are 50–60 *kinemes*, which he groups into *kinemorphic* classes and illustrates using a pictorial notation system called *kinegraphs*, which chart motion using symbols. Birdwhistell would observe speakers and link kinemes with verbal meaning. He believed all behaviors had meaning in the context of verbal communication and could not be separated from it. There were several criticisms of this approach. For example, Dittmann [49] attacked the entire idea that movements are atomic and undermined the whole analogy.

Spiegel and Machotka [51] also criticized the structural approach proposed by Birdwhistell and presented a new formal system for classifying behavior. They classified motion into the following categories:

1) The somatotactical categories of body movement: these categories are a way of classify motion based on its "somatotaxis" or the arrangement of the body in space. A coding system is proposed that is concerned with the formal pattern of movement in body space rather than with the anatomical program of movement that produces the pattern. (127) Patterns of movement are given codes according to their movement within body space, their range in the approach-separation continuum, and their syntropic positioning.
2) An activity series capable of giving the sequence of movements: people learn behavior in an algorithmic way. Harkening back to Darwin's findings, many body movements are the result of cognitive triggers that meet specific needs, even if the action is not completed fully.
3) A set of social roles to provide interpersonal context: a role is a "sequence of acts moving toward a target outcome - the goal - which also describes the function of the role." According to Spiegel and Machotka everyone possesses at least one role, likely more, and these provide cultural context for many behaviors.
4) An event structure or scenario: body motion occurs within a continuous flow of events that has been overlooked in the past. Such a scenario provides valuable contextual information such as a specific social occasion, cultural meaning, and the scale of the vent in terms of people and size of location.

In order to find some validation for their formal system, they performed a series of experiments which involved showing observers a variety of portrayals of interpersonal activity. These range from a nude and clothed Venus, then Apollo, to sketched figures demonstrating various gazes and arm positions. Another series of experiments asked participants to stage wooden figures in response to a described male-female encounter. These experiments provide some validity for the general concepts described in the first part of this work by providing evidence for the claims

about physical body space and context they made earlier. Nonetheless, their methodology involves mostly reasonable observations and statistical inference. However, they did not present any notation system that can be formalized.

Descriptive Approach

What followed was a more descriptive rather than structural approach to nonverbal behavior. Ekman and Friesen [18] present an exhaustive description of the types of non-verbal behavior that people perform. In their 1969 paper [18], they lay out a descriptive system for non-verbal behavior. They discuss three characteristics of an action: (a) origin: how it became part of one's repertoire, (b) usage: the regular external conditions, and (c) coding the type of information conveyed. These behaviors then fulfill one of five general functions in relation to verbal communication: repetition, contradiction, complementing, accenting, or regulating. They reveal five types of acts:

1) Emblems: culture specific, learned behaviors that represent meaning.
2) Illustrators: socially learned behaviors that complement or contrast verbal messages.
3) Affect Displays: Ekman and Friesen argue that the facial display of emotion is universal for the seven primary affects: happiness, surprise, fear, sadness, anger, disgust, and interest. They base their argument on the underlying muscles and physical responses in the face. They also describe various culturally-obtained display rules that modify displays of emotion within various contexts.
4) Regulators: conversational flow gestures that control the back and forth within a dyad.
5) Adaptors: learned actions based on satisfying bodily needs, based on childhood experience. These are then fragmented in adult-hood and experienced in response to buried triggers. These include self-adaptors such as grooming and eating, alter-adaptors such as attacking and flirting, and object-adaptors which are tool-based learned behaviors.

These categories allow the identification and classification of non-verbal acts, as well as helping to clarify why they are performed. They are referenced and used quite frequently by later literature to refer to non-verbal behavior. However, Ekman and Friesen [18] conclude that it "[is] difficult to conceive of non-verbal behavior as a simple unified phenomenon, best explained by a single model of behavior, whether that model be neurophysiologic, linguistic, or psychoanalytic."

Social and Communication

In contrast, Scheflen [52] examines non-verbal communication from the "communicational" point of view, which holds "body movement as a traditional code which

maintains and regular human relationships without reference to language and conscious mental processes" and examines it "in relation to social processes like group cohesion and group regulation." This examination starts by focusing on primate communication and mankind's territoriality that is common to the great apes as well. It also examines bonding behavior and the use of body movement in so-called reciprocals such as aggressive behavior and acts of dominance. As well as identifying the usual body movements such as symbolic gestures and postures and spacing behaviors that frame and punctuate the verbal transaction, Scheflen recognizes verbal discourse as more than a symbolic system for conveying new information; that is, it serves to maintain and make agreeable the existing order. Body language thus becomes a form of human communication that occurs in small, face-to-face groups that employs conventional utterances, facial displays, hand gesture, and touch to keep the couple or group bonded. In addition, Scheflen examines non-verbal behavior in the context of social order. Through the use of examples, he shows how people can live in heavily-bound situations where body language serves to reinforce attitudes of control that aren't being expressed in language. Many family situations can develop in this way: e.g. the overprotective mother who emotionally curtails the development of her child, or the threatening manner in which aggressive racist men might confront a black man while speaking normally.

This work reinforces the idea that body language can be used in a character system to reinforce the role a character plays in a small group, as well as express personal emotion. Since Scheflen's claims are based on observation and psychiatric interviews, these mechanisms are observable in the wild, regardless of whether the theory behind them is conventionally agreed upon. Body language that regulates verbal communication, as well as reciprocals which maintain territory should intuitively make sense. It can also speak to the kinds of social contexts a character may exist within.

Gesture

On another spectrum, there has been much work on the use of body for speech and communication, specifically gesture. McNeill [53] defines gesture as "movements of the arms and hands which are closely synchronized with the flow of speech." An important work in this area is the work of McNeill and Cassell [53–55], who explored the use of communicative gestures by observing and analyzing many cases of people talking about specific subjects, such as real estate, etc. They categorized gestures into the following categories:

- *Iconic gestures*: gestures that represent some features of the subject that a person is speaking about, such as space or shape.
- *Metaphoric gestures*: gestures that represent an abstract feature of the subject that a person is speaking about, such as exchange or use.
- *Deictic gestures*: these gestures indicate or refer to some point in space.
- *Beat gestures*: they are hand movements that occur with accented spoken words.

- *Emblem gestures*: are gestural patterns that have specific meaning within the culture, such as hello or ok.

Our emphasis here is on nonverbal behaviors that represent personality and mannerisms rather than gesture and speech. Thus, we are satisfied by just mentioning this work here rather than elaborating further on it.

Delsarte

During the 19th century, François Delsarte spent over thirty years making observations of the human experience in terms of emotions and movement and comparing them to the principles which guided the sculpting of ancient Greek statuary. According to Stebbins, a student of Delsarte's protégé Steele MacKaye, Delsarte believed that nonverbal behavior is more important than the verbal words as it conveys the inner intent and state more clearly. Based on this belief, he developed an acting style that attempted to connect the inner emotional experience with a systematic set of gestures and movements. Delsarte's work makes much of the Swedenborgian "Law of Correspondence, in the trinity, applied to the art of human expression." [45, p. 397] It should be noted that he himself has never published his work. He trained many people using his system. This training was passed from one student to another. His work was published by his students and his students' students. The best descriptions of his work are in [45, 46]. According to the available literature, Delsarte grounded his work in systematic observations categorizing nonverbal behavior into the following forms:

1. the habitual bearing of the agent of expression
2. the emotional attitudes of the agent
3. the passing inflections of the agent

Delsarte's system divides the body into zones, which are further subdivided into three parts, the mental, moral, and vital subsections. These zones are seen as significant points of arrival or departure for the gesture. Motion which starts from yourself as a centre is termed "excentric"; to yourself as a centre "concentric", and well balanced motion is termed "normal." Delsarte provides meaning for motion made in any of these three ways for each zone of the body. Beyond his sets of laws of motion and form that dictate how and why movement occurs, he provides a practical provision of meaning to each systematic gesture that could be performed. If this system was to be adopted by a human artist, then a system of flexibility exercises is described to allow for limber movement; alternatively, an application to posing statuary is described.

   Delsarte's system for human expression, based as it is upon observation of human interaction as well as ancient art, provides a most intriguing basis for systematizing the movement of believable characters. Being systematic, it lends itself to being adopted by a rule-based system - in fact, it was criticized as artificial and mechanical by some - and stands in need of further empirical testing to determine its overall

validity. So while Stebbins concludes that understanding Delsarte' metaphysics did not bring her commensurate reward, she finds that "Practical Delsartism" lays "the solid foundations of art in expression on which others can build in safety."

Marsella et al.'s saw in Delsarte an exquisite system for believable characters' nonverbal behaviors. They set out to first validate his theory. They started with hand movements [56]. They developed a set of animations that portrayed the hand movements Delsarte suggested and asked participants to interpret them. They then later compared the participant's interpretation with Delsarte's associate meaning of the animation. They concluded that Delsarte's model showed considerable consistency in the subjects' interpretation of a given set of animated hand movements. The next step is to validate other zones he identified and perhaps to develop a model based on his system.

Laban Movement Analysis

Rudolf Laban is considered one of the most important movement theorists of the twentieth century and the founding father of modern dance in central Europe. His lifelong study of movement gave rise to an integrated and holistic system for observing, describing and notating movement and it's inseparability from human expression. Delsarte was among Laban's influences, along with Free Masonry and Rosicrucianism. Laban Movement Analysis (LMA) [57, 58] is an open theory of movement that is applicable to any area of human movement investigation. The body of material known as LMA is an expansion of Laban's original theories through the work of Irmgard Bartenieff, Warren Lamb, Judith Kestenberg and Bonnie Bainbridge-Cohen.

Five categories of movement delineate the full spectrum of LMA's movement parameters: **Body, Effort, Shape, Space** and **Phrasing**. For the purposes of this chapter, we will focus on Effort, which links inner intent to movement qualities and is associated with C.G. Jung's four ego functions: Feeling, Sensing Thinking, and Intuiting (described above). The corresponding Effort factors of Flow, Weight, Space, Time, do not indicate specific actions or gestures, but rather, various ways in which inner intent influences the quality of the gesture. As such, Effort represents a broad parameter space that includes groupings called States and Drives.

The Effort category has become the most widely known aspect of LMA due to its extensive practice within theater. Effort delineates qualities of movement as ongoing fluctuations between Light and Strong Weight, Indirect or Direct Space, Sustained or Sudden Time, and Free or Bound Flow. From these associations, we observe that a mover's Flow of Weight in Space and Time communicates information about physical sensations and the agency to mobilize one's weight with delicacy or force, the broadness or focus of thought, the intuitive leisureliness or urgency of decisions, and the release or control of feelings [47]. The eight Effort qualities emerge in combinations of two elements, forming "states," three elements, creating "drives," and in the rare case of an extreme and compelling movement, four elements combine in a "full Effort action."

Of particular importance for animation and virtual environments is the weight parameter. LMA delineates three Weight parameters: the sensing of one's body weight, and the Passive Weight components of Limp and Heavy.

Effort Overview

FLOW Feeling, Progression, "How": Feeling for how movement progresses

- Free: external releasing or outpouring of energy, going with the flow
- Bound: contained and inward, controlled, precise, resisting the flow

WEIGHT Sensing, Intention, "What": How you sense and adjust to pulls of gravity

- Light: delicate, sensitive, buoyant, easy intention
- Strong: bold, forceful, powerful, determined intention
- Weight Sensing: the sensation of your body's weight, buoyancy
- Passive Weight – surrendering to gravity

    - Limp: weak, wilting, flaccid
    - Heavy: collapse, giving up

SPACE Thinking, Attention, "Where": Thinking, or attention to spatial orientation

- Indirect: flexibility of the joints, three-dimensionality of space, all-around awareness
- Direct: linear actions, focused and specific, attention to a singular spatial possibility

TIME Intuition, Decision, "When": Intuitive decisions concerning when

- Sustained: continuous, lingering, indulging in time, leisurely
- Sudden: urgent, unexpected, isolated, surprising

In animated movement, the illusion of the qualities of weight provides information about the materiality of form in motion. Materiality is intricately bound with intent because the motivation to move and act requires us to mobilize our body mass in constant negotiation with the affects of gravity. One may recognize this negotiation in the difference between the struggle to rise up out of bed in the morning, verses the way one feels on the tennis court later that day swinging an energetic serve.

Another concept of importance is phrasing. Phrasing describes how we sequence and layer the components of movement over time. A movement phrase is analogous to a verbal sentence, or to a phrase of music, in which a complete idea or theme is represented. A phrase unit involves three main stages: Preparation, Action and Recuperation. Our uniqueness is expressed through our movement phrases: individualized rhythmic patterns and preferences of Body, Effort, Shape and Space. How one initiates a phrase of movement organizes intent and patterns the neuromuscular coordination of the action [57].

Every person has his or her own unique patterns of movement. These patterns are deeply embedded movement habits that are integrated with our emotions and

self-expression. A Movement Signature describes the unique movement habits and phrasing patterns of an individual using the descriptive language of LMA. It articulates baseline patterns, as well as what movement choices are made when the mover responds to various stimuli in their environment: interactions and relationships with others, places, memories, problem solving and creativity, play and work, relaxation, exertion, etc. Among his colleagues, Rudolf Laban was known for his ability to intuitively "read" a person based on their Movement Signature.

Warren Lamb worked closely with Laban in the late 1940's [19], and later developed the Shape category of LMA. His interest in behavioral analysis led him to create a theoretical model and assessment technique called Movement Pattern Analysis (MPA), which relates decision-making to non-verbal behavioral styles. These styles are based on the way individuals integrate, or merge Posture and Gesture through rhythmic phrasing of Effort and Shape. Developed as a tool for personnel management, MPA applies a specific interpretive framework to the LMA language.

MPA regards the decision making process as occurring in Stages of Attention (Space Effort, and Horizontal Shaping), to Intention (Weight Effort, and Vertical Shaping) to Decision/Commitment (Time Effort, and Sagittal Shaping). Effort Qualities are indicative of styles of energy Assertion, and Shaping Qualities indicate initiative given to gaining Perspective. The way one changes his/her body shape in space reveals a Perspective within one of the three Planes of movement, and viewed alongside Effort as "complementary aspects of the decision making process" [47], reveals ones interactive style with others as shown in Table 6. For example, an action such as greeting someone with integrated Spreading, then Enclosing them in a hug occurs in the Horizontal plane, and is associated with an Exploring Perspective in the Stage of Attention. Integrated Spreading is complemented with Indirect Space Effort (as if opening one's Attention to a wide-lens focus), while Enclosing is complemented with Direct Space Effort (a singular focus). When these complements occur together, the movement is Sharing in Interaction with others. Laban and Lamb observed that these typical or complementary combinations generally

Table 6 Effort/Shape Affinities associated with the Decision Making Process [47]

ASSERTION		PERSPECTIVE
Investigating	**ATTENDING**	**Exploring**
Correlates with	⇓	Correlates with
Space Effort		**Shaping in the Horizontal Plane**
(directing and indirecting)		(enclosing and spreading)
Determining	**INTENDING**	**Evaluating**
Correlates with	⇓	Correlates with
Weight Effort		**Shaping in the Vertical Plane**
(increasing and decreasing pressure)		(descending and rising)
Timing	**COMMITTING**	**Anticipating**
Correlates with	⇓	Correlates with
Time Effort		**Shaping in the Sagittal Plane**
(accelerating and decelerating)		(retreating and advancing)

Fig. 4 Illustrations showing Posture Gesture Mergers

supported ease and naturalness in movement, and in that sense invited others in. The dynamics of expression in Effort/Shape could also lead to dis-affined combinations such as Indirectness with Enclosing, or Directness with Spreading, which would signal a preference for more privacy in interaction.

The process of shape change in the body occurs through the relationship of Posture (whole body action) and Gesture (action of one body part). Fleeting, unconscious moments of posture-gesture congruence, where postural adjustment supports, or is simultaneous with gestural action, reveal authenticity in one's communication.

The illustrations shown in Figure 4 depict Act 3, Scene 1 from William Shakespeare's Hamlet, in which Hamlet contemplates suicide. Here Hamlet delivers his soliloquy while addressing a skull, held in one hand. Each variation shows a different postural relationship to the gesturing hand, yet the integration of posture and gesture clearly communicates the authenticity of Hamlet's plight during this passionate scene.

These are the baseline movement parameters on which the MPA system is based. Individuals are assessed based on their movement patterns and preferences; the resulting profile reveals which phase of the decision making process they prefer and put most of their energy towards. As Shape is about relating to others, it also reveals the way individuals make decisions as part of a team. This enables managers to employ MPA towards creating effective teams, bringing together employees who compliment each other's approach to achievement [47].

Others have developed applications based on LMA in the areas of psychology and movement re-education based on developmental patterns. Grounding her

work in the observation of infants, Judith Kestenberg developed the Kestenberg Movement Profile, basing her interpretive system in Anna Freud's developmental psychoanalytic metapsychology [59]. Katya Bloom, also working with infants, applies LMA as an observation and communication tool in a movement based psychoanalytic therapy practice. Bonnie Bainbridge Cohen developed Body Mind Centering ⓡ, blending neurodevelopmental therapy with developmental movement patterns that were inherent in Irmgard Bartenieff's rehabilitative movement sequences.

Understanding the Subtle Meaning of Nonverbal Behaviors

Several research projects attempted to explore non-verbal behavior patterns and their links to one particular character attribute: emotion. Wallbott and Scherer [60] present a seminal work in this area. They studied a sample of 224 videos, in which actors portrayed a variety of emotions in a scenario. Through this study, they found that some body movements and postures can be specifically mapped to certain emotions. For example, the posture 'arms crossed in front of chest' is typical of pride, confirmed by Tracy's experiments on pride [61]. In addition, Tom Calvert et al. investigated how emotion is expressed through animation, particularly hand movement [62]. The development of a comprehensive model for understanding the link between nonverbal behavior and emotions is still an open problem.

In our previous study [63], we aimed to extend the studies discussed above in search for a model that links non-verbal behavior to character attributes not limited to emotions. We developed a study to explore the link between the personality models presented in Section 22 and nonverbal behavior described in Section [64]. In particular, we used Fast Food Stanislavsky's model developed by Keith Johnstone (described in Section 22), and set out to explore two questions: (1) how well does this model describe distinct characters? And (2) are there any unique mappings between these character variations and nonverbal movements? To this end, we recruited three animators from the School of Interactive Arts and Technology. We gave them the task of animating ten variations of a simple two-character scenario, where the variations constituted variations in character definitions using the model. The results were mixed. There were some consistencies among the portrayal of specific characters, which indicates a coherent understanding of some of the character attributes used. However, there were also some inconsistencies with specific character descriptions. Nonetheless, the study led us to identify specific nonverbal behavior patterns and led to several lessons on the process and methods for conducting this kind of study. More work is needed to understand the meanings of nonverbal behaviors. We believe the models presented in sections and provide some utility.

Nonverbal Behavior and Adaptive Believable Character

There are several proposed believable character models that fall within the area of conversational agents, such as [55, 65, 66]. The algorithms for these characters specifically focus on the use of gesture and synchronizing it with speech. Readers who are interested in computational models for gestural functionality should start with the references stated above.

There has been a lot of work within the area of believable characters. All such work employed a heuristic based model linking nonverbal behaviors to character attributes, which was usually a best guess model that a researcher came up with or a mixture of motion capture data and some common sense knowledge simulating behavioral patterns that make sense for the developer. For example, one of the earliest and most profound work on believable agents is the Oz project, which was presented in the 90s [67, 68]. In the Oz project, they simulated creatures called Woggles which are circular in shape. For these creatures they developed their own nonverbal behaviors which include a combination of squash and stretch of the entire body or parts of the body, such as the eyes, a model influenced by animation techniques. They also developed an authoring language for encoding character attributes, such as emotions, personality, and attitudes [68]. The nonverbal behavior and their link to character attributes was mostly encoded through this authoring system and mostly based on artistic sense rather than a formal model. Mateas and Stern later extended this system by developing ABL (A Behavior Language), which was used to encode behaviors for their interactive drama Façade. For Façade, Mateas and Stern developed a very expressive set of nonverbal behaviors including patterns of eye movements, posture changes, and hand gestures. All these patterns were also encoded based on artistic sense rather than a formal model [69]. Therefore, the link between these behaviors and the character model is required to be authored by the developer or artist, leading to a very tedious and often static encoding.

To date we only know of one work, the work by Zhao [20] at University of Pennsylvania, that applied movement analysis to animation of adaptive believable characters. Zhao developed a system called EMOTE (Expressive MOTion Engine) which uses Effort and shape qualities from Laban Movement Analysis model as a base model for their character animation. They used motion capture data to acquire and abstract effort and shape parameters from actor motions. They then developed an algorithm that will manipulate these parameters in an already developed key frame or motion captured animation based on the autonomous agents' situation. In particular, Zhao focused on limb and torso movements extracting key pose and timing information of motion capture data. Zhao's work is the only work we found that used LMA in an animated agent architecture. This by itself is a great step forward. However, the model is still limited to limb and torso movements, as discussed by Delsarte hand and head are two other zones that also add towards the mannerisms and aesthetics of body movement. The work also did not establish or explore the link between movement and personality, which is important for a believable character as argued earlier. However, a relationship to personality is inherent in the work, as it is based in LMA, which can be linked to Jungian personality types as described above.

Animation Techniques

The evolution of animated movement at the Walt Disney Animation Studios during the 1930's is key to the formalization of movement parameters for animation. During this era, a core team of animators began to experiment with animated movement. As reported by Frank Thomas and Ollie Johnston in *The Illusion of Life: Disney Animation* [13], Walt Disney pushed the animators to develop their skills and create a more physically believable animated world. Gradually, a terminology, or language of animated movement evolved, which became known as the Principles of Animation. As these precepts are widely known and can be referenced in *The Illusion of Life*, they are listed here with brief definitions:

- Squash and Stretch – elasticity of shapes, maintaining consistency of inner volume.
- Anticipation – the preparation before an action: inclining backwards before moving forwards.
- Staging – posing the action graphically and compositionally for readability and style.
- Straight Ahead Action and Pose to Pose – animating the action chronologically, from the beginning forwards, vs. creating the beginning and ending, then filling in the middle with "inbetween" drawings.
- Follow Through and Overlapping Action – action that sequences from one part to the next. Nothing starts and ends at the same time.
- Slow In and Slow Out – acceleration and deceleration.
- Arcs – use of curved spatial pathways to create actions that maintain volume and form between key poses.
- Secondary Action – movement that happens as the result of the main action.
- Timing – how varied speeds of the same action communicate different meanings.
- Exaggeration – making selected features very pronounced.
- Solid Drawing – maintaining a volumetric quality through all key pose and inbetween drawings.
- Appeal – character designs that support a character's personality and hold the interest of the audience – a character we can empathize with on some level.

Through action analysis classes held on-site, the Disney animators scrutinized live-action footage frame by frame and honed their craft. A richly detailed, full animation style evolved that promoted the physical properties of objects and characters in motion as the basis for believability. The goal was to bring drawings to life and create believable characters through realistic characterization and acting. While the Principles of Animation can be applied to non-character movement, they are specifically geared to support the illusion of life. Note that as soon as you move an inanimate object with Anticipation or Squash and Stretch, it acquires characteristics of motivation and intent.

In recent years, several people have theorized additional Principles of Animation in an attempt to reflect continued developments in animation practice, as well as

the limitations of the original twelve. Walt Stanchfield taught life drawing classes for animators from 1970–1990. He is well known for his expanded 28 Principles of Animation which have been published informally on the internet [70, 71].

While the Principles of Animation have become core concepts used by animators, they do not represent formal models that can be easily computationally formalized. They are also time consuming and inflexible for interactive environments where characters need to be malleable and adaptive as narrative and behaviors change over time induced by users' actions.

In the past few years, there has been a move towards the use of motion capture data as well as tools and algorithms that modify motion captured data. Motion capture is a system usually involving several cameras or sensors placed in strategic positions within the body to capture all intricate details of motion. Such techniques have been extensively used within animation. However, they have also shown great utility within the interactive entertainment industry. Motion capture provides an easy and quick solution to creating animations and encoding expressive behaviors as studios tend to hire professional actors who act out different actions using directions from a director. These animations are then made available for artists to manipulate using algorithms and tools available to them. Thus, most animation techniques within the research community are now targeting the development of routines and tools that take in motion capture data and allow artists to manipulate them. This technique makes use of nonverbal behavior patterns that are encoded in our subconscious without requiring us to uncover or understand these patterns are or what they mean, it is really up to the actor to encode them within the motion captured data that artists can manipulate.

This technique has several disadvantages. First, it is hard to develop animations for creatures other than figures that you can motion capture in real life. Second, while there have been many techniques that adapt the motion capture data depending on the scenario, there are still many open problems within this direction, including naturally blending motion, keeping the personality while blending or transitioning between motions, etc. Third, even though actors are phenomenal at impersonating characters in action, most of the time they do not get the right expression or personality. This is due to the method of acting that is currently taught, namely method acting. This method dictates that actors need to stimulate their emotions from action within a scenario. Since interactive narrative is not set based on specific scenarios and the number of scenarios and contexts differ depending on interaction, a motion capture technique will necessitate capturing motions for all different scenarios that the authors or designers can predict. This was in fact the process used in creating Façade (based on our conversation with the developers). This technique also limits the scenarios within the interactive narrative to the ones that are accounted for. An alternative is to build a model for nonverbal behavior and its link to personality as suggested in this chapter, but the road to this alternative is long.

Animation and Adaptive Believable Character

Several graphics researchers focused on developing real-time algorithms that modify animation routines, such as walk, run, jump, by adding mannerisms, emotions, and personality [62, 72–74]. For example, Perlin created a framework for procedural emotion shaders [75, 76]. The goal of his work is to allow designers to dynamically encode mannerisms for their character animations, and thereby convey mood, emotions, and very simple personalities through the base movements and actions the animators create. An example is adding 'sexy' modification for a 'walk' animation developed by the animator.

One interesting alternative work that made use of specifically Anticipation from the Disney model described above was presented by Bruce Blumberg at the Game Developers conference [77]. His work on Silas is an exciting example of how a simple model of nonverbal behavior can add fluidity and believability to characters. He developed a model that emphasizes on patterns of gaze movement and body movements for a dog based on anticipation. This model was developed based on observation of dog behaviors. The resulting virtual dog was astonishingly believable. Unfortunately, he didn't publish a formal model on nonverbal behavior patterns. It is also unclear if the model can be generalized for human nonverbal behavior.

Conclusions and Open Problems

Developing believable characters has been a major concern of several fields, including animation, computer graphics, and artificial intelligence [78]. It is astonishing that there have been no comprehensive models that formalize nonverbal behavior patterns and their link to character attributes and that can be used for implementing believable characters. This chapter discussed the background theory for creating believable characters, specifically looking into psychology, animation, communication, and acting to create a repository of models that can be used to towards a comprehensive nonverbal behavior model and formulate its link to character attributes.

As the discussion above shows, there is a range of research work that has tackled different aspects of the problem. Personality research has explored the development of character attribute models. We have presented research from the fields of psychology, sociology, communication, acting, kinesiology, and ergonomics, which have all offered formalizations and explanations of nonverbal behavior. However, there are still several important open problems that need to be resolved to create adaptive believable characters.

One open problem is the development of a verified and validated model for patterns of nonverbal behavior and what these patterns mean. Another is in understanding how animators compose personality through intricate nonverbal behavior patterns, having significant impact on how character is read by the audience. A bigger goal would be to understand the link between nonverbal behavior patterns and

character personality, or what nonverbal behavior patterns we tend to associate with various character types. Yet another important direction is the development of tools that encode such patterns and their link to personality, thus allowing artists to be more creative with these personalities at a much higher level, rather than struggle with low-level design of personality and their link to nonverbal behaviors.

Aside from computer science, interactive entertainment, or serious games, the development of research projects that tackle these goals will have broad contributions to different communities. Deepening our understanding of nonverbal behavior through these application areas is in itself a contribution to our understanding of human behavior.

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