Person–Robot Interactions From the Robopsychologists' Point of View: The Robotic Psychology and Robotherapy Approach

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Invited Paper

Recent research shows that people perceive and treat robots not just as machines, but also as their companions or artificial partners. Person–robot communication, viewed as a complex interactive system (CIS), is based upon three basic principles: interactivity, equifinality, and multimodality. Classification of artificial creatures from the robopsychologist's point of view divides them into two major groups: assisting robots, which are oriented toward industrial, military, research, medical, and service activities, and interactive stimulation robots, which are designed for social, educational, rehabilitation, therapeutic, and entertainment purposes. The latter class is considered the primary subject for the robotic psychology and robotherapy, approaches that have been developed by the authors. These new fields consist of a concept that places the relationships between humans and robots into a psychological, rather than technological, context. Conceptual and experimental results of implementing the robotic psychology and robotherapy concept into the study of human–robot interactions concern basic operational definitions, theoretical framework, and the design of a unified assessment tool named the Person–Robot Complex Interactive Scale (PRCIS). A study with a robotic cat provides the first results of cross-cultural analysis of person–robot communication, as well as findings on the robot's use by children, young and older adults, and elderly persons with dementia.

Keywords*—*Assessment of person–robot communication, complex interactive systems (CIS), cross-cultural study, cyberanthopology, dementia, interactive stimulation robots, robotherapy, robotic cat, robotic psychology.

I. Introduction. A New Paradigm of Human–Robot Interactions

> *In 2008 she obtained her Ph.D. and joined United States Robots as a "Robopsychologist," becoming the first practitioner of a new science…Robbie was constructed for only one purpose really—to be the companion of a little child.*
> *—Isaac Asimov (1940) [1]*

In a predigital era, people used to think of robots as mechanical wonders. According to the predominant industrialized worldview, artificial creatures were evaluated in terms of mechanisms, assuming by default that they possess only pure engineering value. Therefore, mechanical creatures—predecessors of the contemporary digital robots—were treated as machines aimed at easing work tasks that involved difficult manual labor or martial cogs capable of changing a course of military operation. However, together with the technological interpretation, another meaning has always been implied. Many artificial creatures were designed for the purposes of leisure and entertainment. A history of human–machine coevolution reveals such marvels as ancient Greek entertainment robots designed by the engineer Ctesibius (*ca.* 270 B.C.) [2], and an 18th century Japanese automatic tea carrying doll based upon Karakuri technology [3]. (For more details on evolution of human–robot coexistence, see [4].)

A genuine interest in artificial creatures passed throughout the centuries, from the ancient engineer to the modern designer, as a silver lining of technological tribute to the human culture. The recent merger of engineering and humanistic approaches for the enrichment of human life has become a starting point for new developments in the 21st century. Researchers in many fields have witnessed a paradigmatic shift in robotic sciences from the "mechano-centric" to "human-oriented" principles that have transformed the very purpose of artificial creatures' existence, together with their engineering design and physical appearance [5]–[7].

The shift toward human values within technological processes mirrors the complexity of living beings. Thus, the diversity of the living world is one of the main features

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Table 1
Classification of Robots With Regard to Human Needs and Benefits

ROBOT			PERSON	
Type	**Physical appearance**	**Behavioral configuration**	**Need**	**Benefit**
Assisting robots				
Industrial robots	Machine–like appearance adjusted to the specifics of an executing function	Consists of basic physical movements with the purpose of providing mostly motor or sensory-based activities	To perform hard labor and hazardous work	Increase in productivity
Research robots			To expend and refine human sensors	Ability to obtain new scientific data
Military and rescue robots			To act in life-threatening situations	Safety of human beings
Medical robots			To carry out diagnostic and treatment of the human body	Health maintenance
Service robots			To help in performing activities of daily living	Housekeeping
Interactive stimulation robots				
Social robots	Anthropomorphized appearance or animated form of existing and non-existing beings or objects	Imitation of human facial expressions and complex gestures with social meaning or modeling basic emotional states and life-like behaviors	To provide company	Communication
Recreational robots			To stimulate engagement in educational process	Positive stimulation through entertainment
Educational robots			To entertain	Enrichment of learning skills
Rehabilitation robots			To recover from injury or to compensate for existing disability	Medical treatment and aids through rehabilitation
Robots with therapeutic potential			To alleviate negative mental states and psychological dysfunction	Therapy of negative states and behaviors

contained in artificial creatures. Artificial creatures have their own distinct individuality, which manifests itself in the robot's design and behavioral configurations. In the same way people and other living beings differ from each other by various parameters, such as weight and height, behavioral reactions and character, emotions and cognition, and abilities and coping strategies, robotic creatures also can be distinguished from each other. From a psychological point of view, robots are capable of playing different roles, appearing as a human companion, educator, explorer, entertainer, rehabilitation or medical assistant, and even psychological therapist.

The diversity of human activities requires a variety of robotic creatures that might be involved with those activities. From the perspective of human needs, all kinds of interactions between people and robots deserve close psychological attention. Interdisciplinary research based upon technological and psychological achievements lies at the foundation of the new, nontraditional area of robotics. A technological evolution of robotic creatures developed their ability to interact with children and adults with physical and cognitive disabilities [8]–[10], emotional and communicational disorders [11], [12], and elderly persons with social problems [13]–[15]. In the present day, robots are used as social [7], recreational [16], [17], educational [18], [19], rehabilitative [11], [12], and therapeutic [20]–[22] tools.

A primary classification (see Table 1) of "smart" automats that have come into being in recent decades considers two types of criteria. On one hand, it accounts for the roboparameters such as robot's behavioral configuration, defined by the degrees of freedom, robo-IQ (complexity of artificial intelligence corresponding to both hardware and software hierarchies, and degree of uncertainty in the tasks performed) [20], and the robot's physical properties manifested in their appearance. On the other hand, this classification takes into account the purpose of a robot as it relates to human activity, and a person's preferences, needs, and benefits. In a psychological context, the whole variety of robotic creatures can be divided into two major classes—assisting robots and interactive stimulation robots. Machine-like assisting robots are oriented toward industrial, military, research, medical, and service tasks while satisfying vital human needs in performing hazardous labor and assisting in daily living, carrying out space research missions, or acting in life-threatening situations. Stimulating robotic creatures, which tend to have an anthropomorphized appearance, are aimed at performing social, educating, entertaining, rehabilitative, and therapeutic activities while engaging in educational or therapeutic processes or simply providing company. Psychology contributes to the first class of robots by studying ergonomic parameters that influence the quality of their performance. The psychological impact on the development of the second class of robots—as we will see in the following sections—is more dramatic and especially challenging.

II. Class of Interactive Stimulation Robots

The development of engaging robotic creatures has triggered a need to study the consequences of robots' implementation into one's life. Furthermore, the class of interactive stimulation robots (see Table 1) is distinguished by two characteristics that make it potentially valuable for robopsychology and robotherapy. A first major distinction of interactive stimulation robots is that those creatures are designed for the purpose of communicating with a human being on a "personal" level. This type of personalized robot can be called an "artificial partner" [23]. The concept of an artificial partner places the relationships between humans and robots into a psychological, rather than technological, context. A few features depict an artificial partner as a good human companion.

- It imitates a real life (human- or animal-like) behavior.
- It models motor, emotional, and cognitive behaviors normally experienced by animals or humans.
- It communicates with a person on various levels: tactile–kinesthetic, sensory, emotional, cognitive, and social. These communications can be characterized using both verbal and nonverbal modes, and they can be evaluated as positive or negative.

The above-indicated parameters make an artificial creature an interesting and engaging communicating, gaming, educational, or even therapeutic partner for people of all ages, cultures, and life experiences (see experimental results in Section VI).

A second major distinction is that robots of the class of interactive stimulation artificial creatures are perceived as part of living and imaginary worlds. They exist in the forms of:

- anthropomorphic robots or humanoids;
- robots imitating animals;
- artificial creatures imitating living beings other than humans or animals (e.g., fictitious creatures).

All together, these two major distinctions help to differentiate between the human-oriented class of interactive stimulation artificial creatures, and the mechanically oriented class of assisting robots. An ability to communicate with humans on personalized level, as well as a lifelike appearance makes interactive stimulation creatures valuable psychological agents.

III. Person–Robot Communication as a Complex Interactive System

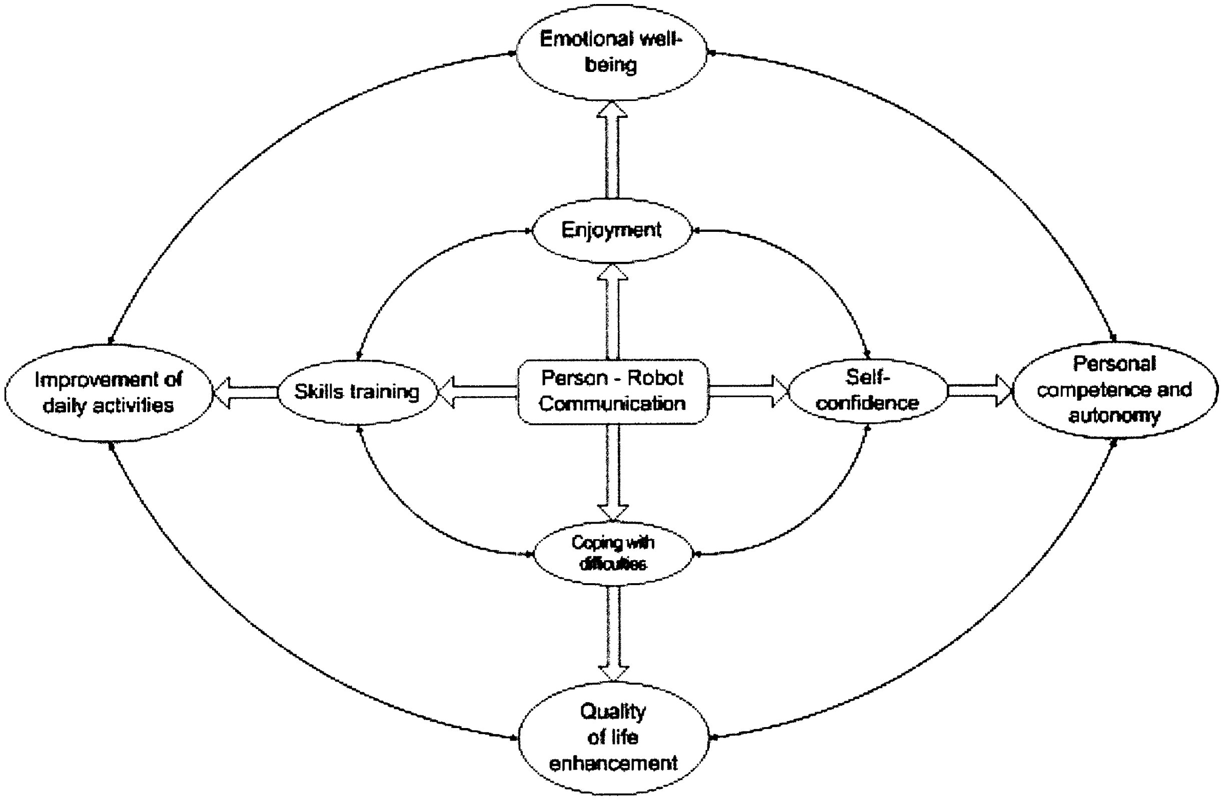
Interactions between artificial creatures and persons exist in many dimensions. In the context of a complex interactive system (CIS) approach, a person–robot communication can be analyzed as a hierarchically organized configuration of signal exchanges mediated by both the technological and social environments. We use the term "complex interactive systems" [23] to emphasize the multiplicity of interplay between human and artificial minds and bodies for several reasons.

First of all, a robot as an embodied digital agent coexists with an interacting person in the same given space–time continuum [24], [25], thus becoming an interactive agent. The robot's interactive quality is vitally important for people with special needs and limited resources, i.e., physical, cognitive, or emotional impairment, or persons who strive toward further development through mastering certain skills.

Second, since an interactive system behaves equifinally ("the same goal can be reached from different initial conditions or in different ways," as von Bertalanffy pointed out [26]), robots with various levels of artificial intelligence and types of sensory feedback can benefit people with different combinations of skills and abilities in a very broad context of individual situations. The universal principle of equifinality allows for the ability to modify the robot's configuration in a way that suits the endless variety of human individualities.

Third, the multimodality of person–robot communication produces an integrative effect resulted in the unique match between a robot's behavioral configuration and a person's individual profile. All of the above is summarized in Fig. 1, which presents a multidimensional model of person–robot communication as a CIS. The model was developed with the use of available data derived from studies conducted at the crossroads of social robotics, computational entertainment, human factors, differential psychology [27], and studies on positive coping with difficult situations [28]. For this example, we use a prototype described elsewhere [23].

A CIS of the person–robot communication is formed by two loops. The internal loop consists of the goal-oriented patterns that reflect people's interest in and motivation for communication with robotic creatures. Skills training, enjoyment, self-confidence and coping with life difficulties are among basic objectives of robot-mediated activities. The external loop embraces the results of internal loop functioning, such as improvement of professional or daily activities due to physical rehabilitation, sensory–motor, or cognitive training; increase in emotional well-being through positive stimulation and enjoyment; enhancement of personal competence and autonomy by achieving a sense of control and self-confidence; and enhancement in the quality of individual life through mastering of activities of coping with life difficulties. Interactions between the two loops produce such integrative effects as compensation for diminished or lacking abilities; optimization of sensory–motor abilities and cognitive and emotional functioning; and, finally, psychological enrichment of humans' lives.



Note to Fig. 1. The corelations between system parameters (skills, enjoyment, self-confidence, and coping) and interaction effects.

Skills training: physical rehabilitation, sensory–motor stimulation, attention, and memory.

Enjoyment: providing positive stimulation.

Self-confidence: developing a sense of control.

Coping with life difficulties: psychological diagnostic, identification of problem areas, and evaluation of needs.

Fig. 1. Multidimensional model of a person–robot communication as a CIS.

As we can see, robots, whose ultimate destination is to fulfill human needs and desires, are no longer satisfying people with just their role as tools for exploring, reconstructing, or utilizing the natural environment. Artificial creatures are rapidly becoming good companions, helping people to cope with a wide range of disabilities, loneliness, depression, and other negative states. Robots' potential ability to enhance human well-being paved the way for new directions in modern psychology.

IV. Robotic Psychology and Robotherapy as Personal Dimensions of Technological World

The robotic psychology and robotherapy approach focuses on the psychological significance of person–robotic creature communication. The main statement of our approach is that willingly or unwillingly, humans create an artificial universe and its inhabitants by projecting their own image along with the features of the world in which they live. In the world of robotics, the most important and somewhat unexpected challenges are associated with the fact that advanced artificial creatures with a high robo-IQ [29] (which reflects the complexity of the software-based artificial intelligence related to an adequate performance of an uncertain or multiple-choice task and sophisticated synthetic sensory systems) might be effectively used in different kinds of psychological applications, playing such roles as:

- a mediator in person-to-person communication;
- an interactive device for training and development of certain skills;
- a "smart" tool for guided physical and mental stimulation;
- a human companion in unusual situations and difficult life circumstances.

Robotic creatures of the interactive stimulation class have become the primary subjects of a new field of study named robotic psychology and robotherapy [30].

We define *robopsychology* as a systematic study of compatibility between people and artificial creatures on many different levels, such as sensory–motor, emotional, cognitive, and social [29]. Robotic psychology studies individual differences in people's interactions with various robots, as well as the diversity of the robots themselves, applying principles of differential psychology to the traditional fields of human factors and human–computer interactions. Moreover, robopsychologists study psychological mechanisms of the animation of the technological entity which result in a unique phenomenon defined as a robot's "personality."

Robotherapy can be defined as a framework of human–robotic creature interactions aimed at the reconstruction of a person's negative experiences through the development of coping strategies, mediated by technological tools, in order to provide a platform for building new positive life skills [31]. In a broader sense, the innovative concept of robotherapy offers methodological and experimental justification for the use of nonpharmacological interventions based on stimulation, assistance, and rehabilitation techniques for people with physical and cognitive impairments, special needs, or psychological problems. The goal of psychologically oriented therapy in studying person–robot interactions is twofold: 1) offering a research-justified modification of the robotic creature's appearance and behavioral configuration that will be well suited for the particular type of psychological and physical profile (e.g., specially designed robots for persons with depression, cerebral palsy, attention deficit disorder, sensory disintegration, dementia, physical immobility, anxiety, autism, loneliness, etc.) and 2) providing individually tailored nonpharmacological interventions based upon people's needs and preferences.

A founder of modern cybernetics, Norbert Wiener, pointed out that a major function of sophisticated communicative machines is the ability to resist entropy by modifying their behavioral configurations on the basis of past experiences and the use of sensitive feedback [32]. This idea lies at the very foundation of robotic psychology and robotherapy, wherein a robot plays the role of an interactive agent communicating with a person in different modes by promoting physical, sensory–motor, emotional, and cognitive stimulation, and—most important—providing an individual with psychological benefits (e.g., sense of control, independence, and self-efficacy).

Robotic psychology and robotherapy currently focus on elaborating theoretical and applied justifications in order to embrace and analyze the epistemology and phenomenology of a diverse robopopulation.

V. Psychological Value of Artificial Creatures: Robots as Interactive Agents

Although all kinds of robots can be studied with psychological methods, the present paper focuses on the robotic creatures that belong to the class of interactive stimulation robots. As of today, numerous interactive artificial creatures equipped with touch, audio, and visual sensors as well as different levels of robo-IQ already exist on the market and in the laboratory. The most vivid examples are the anthropomorphic robot platforms Cog and Kismet [33], [34]; Doc Beardsley [35] and Nursebot Pearl [36]; intelligent humanoids AMI [37], HERMES [38] and ASIMO [39], the robotic cats Tama and NeCoRo [40], the robotic dog AIBO [41] and a therapeutic robot seal Paro [42], and the automated doll My Real Baby [43]. The psychological value of this class of robots is based upon the unique combination of such features as interactivity, lifelike appearances, and imitating behaviors.

It is worth mentioning that interactivity of the robotic creatures plays the same role in organizing artificially simulated behavior as intentionality plays in human behavior. A dramatic transformation of the robot's role in human life is associated with their growing ability to participate in traditionally human activities such as teaching, training, and treatment.

In the following subsections, we will discuss how robots, viewed as interactive agents, are used in such traditionally human-oriented activities as social communication, education, entertainment, rehabilitation and psychological therapy.

A. Interactive Robotic Creatures as Social Agents

A robotic creature is perceived as the social agent if it models people's social behavior, and is filled with such subtle cues as eye contact, gestures and emotional responses recognizable only in their appropriate social context. Only a few robots are capable of handling this difficult task. The robot Kismet, designed by Braezeal *et al.* [7], became one of the first social agents. Designers applied a developmental psychology approach to the creation of this autonomous robot, which was built at the Massachusetts Institute of Technology (MIT), Cambridge, Media Lab in 1998. The humanoid Kismet models the natural process of communication and is able to learn through social interactions.

The sociable robot–android AMI, developed by Yang *et al.* [37] is able to communicate with humans through multimodal dialogue. In addition to nonverbal and verbal modes of communication, AMI has a body-mounted display that provides affective stimulation by changing colors that are associated with a variety of human emotions.

Robotic social agents take after not only humans but animals as well. Cats, dogs, birds, and other living beings have been known as human companions for centuries. A partnership between people and their pets inspired engineers to create a whole generation of robotic animals. In the context of robotic psychology, compatibility between humans and robots depends on how we perceive our artificial partners and how we feel about them emotionally. Robotic pets' resemblance of real animals and associated human experiences allowed Kahn *et al.* to study the influence of communication with robots on children's cognitive, social, and moral developmental processes. Children's conceptualization of the robotic creatures' behavior was similar to their perception and reasoning based on experience with real pets [15].

Despite a similarity found between robotic and real pets, research shows that perceptions of the robots differed from the people's perceptions of animals, other humans, and inanimate objects. In a study conducted by the Sakamoto Laboratory, Ochanomizu University, Tokyo, Japan, in collaboration with the NEC Company, three robotic creatures—the robotic dog AIBO and humanoids ASIMO and PaPeRo—were compared with each other as well as with animals, humans, and inanimate objects [44]. The most important association was found between the robotic creature's physical properties and its acceptance as a social companion. The appearance and shape of the robots influenced the level of comfort people experience around technological devices and especially robotic creatures.

B. Interactive Robotic Creatures as Entertainment Agents

Artificial creatures whose abilities fully revealed themselves in a gaming situation can be called entertainment agents. In some sense, each group of the class of interactive stimulation robots may perform an entertaining function. The most famous entertaining robots are the robotic dog AIBO and the singing and dancing robot SDR-4X [45], both manufactured by Sony; the walking humanoid ASIMO (produced by Honda) with the extended ability to keep balance and climb the stairs [39], and the joke-telling Doc Beardsley [35]. Entertainment agents play a role of a mediator in an entertaining process and stimulate the human imagination by creating a sense of presence. The latter is one of the main integrative effects produced by person–artificial creature interactions.

Specific features of interactive stimulation robots included in a group of entertainment agents illustrate that sense of presence might be achieved through engagement with the robotic creature in the same way as through involvement with a virtual agent (e.g., a computer game character). The main effect of interactions between a person and an entertainment agent was the production of positive emotions such as amusement, joy, and pleasure.

C. Interactive Robotic Creatures as Education Agents

A robot's appearance influences not only people's perception of it as a communication partner, but also their acceptance of it as an educator. Besides the robot's IQ and communicational ability, its unique anthropomorphic characteristics play a crucial role in the learning process. Research shows that children aged three to five were motivated to learn from a personified mobile robot with a smiling face and verbal positive reinforcement much more than from an immobile and nonverbal machine-like device [46].

Analysis of children's needs and preferences resulted in the creation of a realistic robotic doll called My Real Baby [43]. This doll has soft and flexible skin, a rich vocabulary of sounds and words, and articulated facial expressiveness. In addition, My Real Baby manifests 15 human-like emotions of different intensity. An automatic doll allows children to develop educational play experiences triggered by their own imagination and creativity through the robot's lifelike responses expressed in emotionally appropriate ways.

D. Interactive Robotic Creatures as Rehabilitation Agents

Rehabilitation robots are designed to assist mentally and physically impaired people in performing activities of daily living. Rehabilitation robotic agents help disabled persons to maintain their autonomy and self-efficacy by compensating for lacking abilities, training diminished skills, and enhancing a sense of control. Lancioni *et al.* developed a robot-assisted occupational program that provides choice opportunities for people with severe mental retardation and multiple handicaps [10]. In another study, a set of robots with different designs and functionality were employed for a group of neuropsychologically impaired persons in order to compensate for their limited cognitive and physical resources. Beneficial symbiosis was achieved by matching the robots' capacity to provide visual, auditory, and motor support, as well as communicative stimulation, with the individuals' comprehension abilities, physical needs, and communicational styles [47].

The anthropomorphic robot CosmoBot, invented by Lathan's team at AnthroTronix, Inc., Silver Spring, MD, is designed to be a companion for children working on developmental goals associated with physical, occupational, and speech therapy. CosmoBot detects the child's movements and voice commands and responds to them with its own voice and movements. This rehabilitation aid is programmable, leading the child to interact with the robotic creature in the context of new games and stories. The robot's data collection capabilities allow therapists and educators to objectively track the individual's progress in addressing developmental goals [12].

Druin *et al.* at the Human Computer Interaction Laboratory, University of Maryland, College Park, developed a robotic aid named Personal Electronic Teller of Stories (PETS) [11]. Children can customize the appearance of PETS using different animal parts (dog paws, wings, horns, etc.) to provide the robot with personal representation. To communicate how they feel, children create stories and program PETS to express their emotions through the robot's movement and sound. This method of communication gives children with special challenges a sense of control and fulfillment. Through interactions with the robot, children overcome their own limitations of emotional and verbal expression. A storytelling robot has the potential to provide effective therapy for emotionally and cognitively challenged children.

E. Interactive Robotic Creatures as Therapeutic Agents

Over the last few years, a group of engineers and researchers developed a new class of lifelike robots called artificial emotional creatures. Recent examples are the robotic cat NeCoRo and the robot seal Paro. A new concept of artificial emotional creature [48], [49] employs fuzzy logic, which characterizes a robot's artificial intelligence and makes its behavior "unpredictably" engaging for the human mind. Another distinct feature of emotional robotic pets is the built-in tactile sensors covered with the "skin"—a synthetic fur—which make them responsive to the human touch. Lifelike appearance, mimicking behavior, and the possibility to provide tactile stimulation create a therapeutic value that is missing in many other robotic models.

Research with the robot seal Paro is aimed at studying the psychological, physiological, and social effects of robotic pet interactions with both children in the hospital setting and elderly persons who reside in the nursing home. Results have shown that physical interaction mediated by the robot's tactile sensors positively influences subjective evaluation of the artificial creature appearance. Analysis of the responses of 641 participants, who evaluated different features of the robot seal Paro, revealed two general factors that characterized individual experiences of interacting with the emotional robot. The first factor was related to the

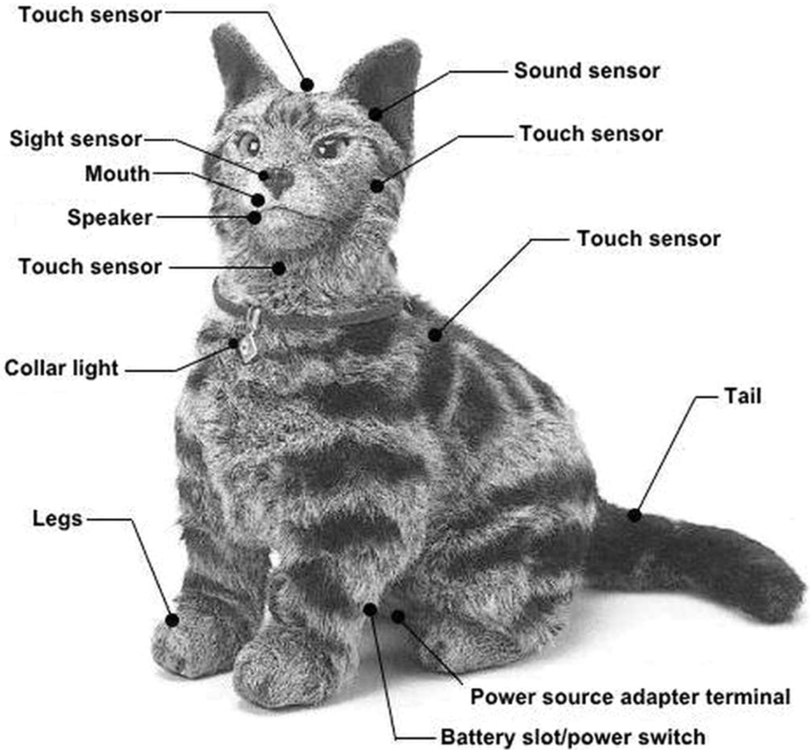


Fig. 2. Robotic cat NeCoRo—a subject for the Robopsychology and Robotherapy Project.

unique tactile properties of the artificial creature, while the second factor was associated with its communicative value [42]. Analysis of psychophysiological and psychological indicators in the context of therapeutic effects produced by the human–robotic seal interactions showed that the texture and softness of Paro's synthetic fur in combination with the creature's empathic appeal had a positive effect on the mood and associated state of comfort in interacting persons of different ages, gender, medical, and cognitive status [21], [50].

A study with another therapeutic robotic agent—a cat called NeCoRo [51]—is discussed in detail in Section VI as an illustration of methodology that is based upon the robotic psychology and robotherapy concept.

VI. Robotic Psychology and Robotherapy Approach: A Study of Individual and Group Differences in Person–Robot Interactions

A critical task for the robotic psychology and robotherapy approach is the analysis of individual and group differences (e.g., age, gender, culture, life experiences, psychological profile, etc.) manifested through person–robot interactions. Numerous experimental facts demonstrate that the human-oriented paradigm of robotic sciences also requires a unified methodology in studying a robot's personality.

A study presented below was aimed at a psychological examination of the wide range of human reactions emerging from communication with an artificial creature, in this case, the robotic cat NeCoRo. In this project, we implemented a conceptual design based on the congruence between living and artificial systems.

A. Robotic Cat NeCoRo as a Research Tool

To understand the psychological effects produced by interactions between a person and an artificial creature, we organized a study which involved people of different ages, genders, and cultures. The robotic cat NeCoRo (see Fig. 2), manufactured by the Omron Corporation, Kyoto, Japan, was chosen as a subject for our research. This cat-type robot is alternatively called a mental health robot [51]. Fifteen actuators inside the robotic creature's body make its behavior believable by providing adequate responses to human voice, movements, and touch. Multiple built-in sensors together with an artificial intelligence produce NeCoRo's self-organizing behavior. The real-life-looking robotic cat creates a playful, natural communication with humans by mimicking a real cat's reactions. NeCoRo can stretch its body and paws, move its tail, open and close its eyes, and meow, hiss, or purr when it is touched or if someone speaks to it.

A multisite project with the cat NeCoRo, which we named Max for the purposes of psychological identification, serves as an example of how general principles of the robotic psychology and robotherapy approach might be applied to the analysis of individual and group differences in interactions between a sophisticated robot with artificial intelligence and sensory feedback and persons of different gender, age, culture, mental and physical status, and life experiences.

B. The Person–Robot Complex Interactive Scale—A Unified Methodology for Assessing Interactions Between Humans and Artificial Creatures

An understanding of behavior of any nature starts with a qualitative and quantitative assessment of its structure and phenomenological manifestations. In order to analyze how people perceive and interact with digitally embodied agents such as robots of different kinds (see Table 1), a unified assessment called the *Person–Robot Complex Interactive Scale (PRCIS)* was designed [30]. This diagnostic tool, aimed at measuring person–robot interactions, considers the diversity of both humans and artificial creatures. Human factors account for biological (e.g., sex, age, disabilities of organic nature), psychological (e.g., individual differences in sensory–motor, emotional, and cognitive processes, personal preferences, and life experiences), and social (e.g., ethnicity and socioeconomic status) parameters. Robotic creatures are analyzed through physical (e.g., hardware architecture), aesthetic (e.g., appearance and appeal), and behavioral (e.g., responsiveness and "smartness") parameters.

In the context of the robotic psychology and robotherapy approach, human–robot interactions are viewed as a complex multidimensional system. Therefore, each pattern evaluated using the PRCIS is assigned a certain psychological value, which is associated with a person's past life experiences, likes and dislikes, and emotional, cognitive, and behavioral traits and states. The *PRCIS* items were developed as a result of both literature-based meta-analysis and our own phenomenological and experimental data derived from direct observations of interactions between people and robots. After developing a primary structure, observations were recorded on video and later examined by two independent evaluators. Interrater reliabilities for observations averaged 0.92. Data and experimental profiles were studied further with inferential statistics and content analysis. Coherent patterns that characterize the robotic creature's behavior and human actions together with their possible responses formed four basic frames, described as nonverbal, verbal, emotional, and animated modes of communication.

1) Structure of PRCIS: The structure of the PRCIS reflects a hierarchically organized process of person–robot communication. The first layer is formed by four universal interactive patterns: nonverbal, verbal, emotional, and animated. A second layer is presented by secondary patterns that describe each universal mode of interactions in terms of particular activity (e.g., the nonverbal scale consists of two subscales, tactile and manipulative interactions). A third layer characterizes each interaction through positive (e.g., verbal personalized approval of robot's behavior: "You are such a good fellow!"), or negative (e.g., nonverbal manipulative activity with negative connotation such as hitting or striking the robot) displays. Presented below are some examples and brief descriptions of the PRCIS subscales (Note: For the full version of the scale, contact the authors).

The nonverbal interaction scale includes tactile and manipulation subscales:

Tactile subscale: Takes into account specifics of the participant's tactile interactions with the robotic creature, such as cautiously touching the robot's body with one or two fingers or stroking firmly with an open palm.

Manipulative subscale: Captures specific components of the participant's manipulations with the robotic creature, for instance, whether the participant holds the robot or plays with it.

Verbal interaction scale measures whether and how much a participant interacts with the robot through voice. This scale differentiates between types of verbal behavior such as direct orders (e.g., "Don't do it!") or friendly engagement commands (e.g., "Let's play together"). The scale indicates whether a participant expresses verbal approval or disapproval or talks with the robot as if it were a living being.

Emotional display scale measures the participant's positive and negative emotional responses to the robot's behavior.

Negative display subscale: Evaluates whether or not the participant expresses negative feelings toward the robotic partner. Other parameters identify if a participant is nervous, afraid of the robot, or frustrated by its presence and if the participant ignores the robotic creature, expresses anger toward it, or remains aloof.

Positive display subscale: Estimates constructive emotional reactions of the participant and covers a wide range of positive emotions from curiosity, joyfulness, and excitement to tenderness, pleasure, and playfulness. Emotions included in this subscale differ by the intensity and specifics of their manifestation.

The animated interaction scale assesses perception of and attitudes toward the robot. It measures if a participant personalizes the robotic creature or treats it as a simple technological device. The following behaviors are identified as animated interactions: a participant looking directly into the robot's eyes or using different objects to trigger the response of the robotic creature; a participant performing "*as if*" activities such as feeding or putting the robot to sleep. The scale also takes into account whether the participant creates gaming situations by developing new ways of interacting with the robot.

2) Design of PRCIS: The PRCIS includes: 1) assessment of a person's individual style of communication with the robotic creature based on instructor's direct observations; 2) the instructor's overall evaluation of the session; 3) the participant's evaluation of his/her new experiences with an interactive robot; and 4) the participant's evaluation of the robotic creature's features, advantages, and disadvantages, as well as their past personal experiences with modern technology.

PRCIS documentation consists of four parts: two sections for the instructor's evaluation and two sections for the participant's self-assessment.

Instructor evaluation forms (Parts 1 and 2): The instructor conducts an assessment of nonverbal interactions, including tactile and manipulative patterns of person–robot interactions, the participant's verbal responses, specifics of his/her individual animating style, and emotional aspects of communication with the robot during the session. The participant's overall involvement with the interactions is also specified as a separate category in the scale. The instructor's overall evaluation of person–robot interactions consists of a multiple-choice scale that includes the general mode of the participant's behavior (from disruptive to interactive), overall verbal and nonverbal intensity of communication, level of engagement, and the participant's predominant mood.

Participant evaluation forms (Parts 3 and 4): Participant forms are aimed at evaluating the robot's behavior and features, as well as the participant's likes and dislikes regarding communication with the robotic creature. Also, the participant is given an opportunity to express their opinion about the robotic creature's advantages and disadvantages through open-ended questions. Another part of the participant's section includes a special subscale regarding the person's specific life experiences (e.g., experiences with modern technologies). If a self-administered assessment cannot be obtained (e.g., small children or persons with cognitive or sensory impairment), this part of a scale is analyzed via a unified coding system.

The instructor's and participant's evaluation forms account for both negative and positive displays and measure all behaviors via a five-point Lickert-type scale. Each mode is characterized in terms of intensity of interactions from one (lowest score) to five (highest score), and for some items, a multiple-choice answer format is provided. This universal structure of PRCIS can be adjusted for a particular type of robot. It was used in our study with the robotic cat NeCoRo presented in the next sections.

C. Robopsychology and Robotherapy Experimental Study: Sample and Procedure

The study involved more than 80 individuals of both genders, ranging in age from 8 to 92 years. Participants had different experiences with live pets and modern technology. A project was initiated and coordinated through the Institute of Robotic Psychology and Robotherapy at CyberAntrhopology Research, Inc., Chevy Chase, MD. The data on Japanese participants included in the cross-cultural part of the project were collected by Dr. Ojika, Dr. Nishimoto and their colleagues from Gifu University, Gifu, Japan [52]. The major portion of the American participants' data was collected at the Friendship Heights Community, Chevy Chase. A pilot project, which involved elderly persons with dementia, was conducted in collaboration with Dr. Jiska Cohen-Mansfield and the research team at the Research Institute on Aging, Rockville, MD [53].

Research Objectives: The project's overall goal was to show how individual (e.g., age, sex, past experience, level of cognitive functioning, and communication style) and social factors based upon cultural traditions influence the specifics of interactions between a person and a robot. The research examined preferences in communication with and features of the robotic cat NeCoRo through the analysis of: 1) age and gender differences in person–robot interactions; 2) cross-cultural specifics of interactive patterns; 3) influence of a person's past experiences with live pets and modern technology on the communication with the robot; and 4) impact of the robotic interactive creature on emotional and behavioral responses in persons with different levels of cognitive functioning.

Procedure: Prior to the study, an informed consent was obtained for each participant. A standard procedure was employed over the course of study (with some modifications in the group of persons with dementia). Each participant received a 15-min interactive session with the robotic cat accompanied by a standardized introduction. During the session an instructor observed the participant's behavior and evaluated the quality and intensity of the interactions via *PRCIS, Part 1 (Instructor's observational assessment)*. Observations were performed twice—during the first and the last 3 min of the session. Each session was videotaped for further quantitative and qualitative analysis. A second instructor's evaluation was performed via *PRCIS, Part 2 (Instructor's overall evaluation)*, which summarizes observational experiences during the session.

After completion of the session, a participant evaluated his/her own experience with the robotic creature as well as its features, advantages and disadvantages through *PRCIS, Part 3 (Participant's evaluation of new experiences)*. The participant's past experiences with live pets and modern technologies were evaluated via *PRCIS, Part 4 (Participant's past experiences)*.

In a group of nursing home residents with dementia only instructor's evaluation was implemented. Past experiences were studied through an interview with a close relative.

D. Research Design, Experimental Results, and Discussion

Due to space limitations, the discussion of results is presented together with the data analysis.

1) Cross-Cultural Study on Robotic Psychology: A study regarding American and Japanese perceptions of and communications with the robotic cat was based upon a cross-sectional comparison research design. The instructor's evaluation of and responses from each of the 32 participants (16 Americans and 16 Japanese) of both genders and two age groups (20–35 and 65–79) who participated in a 15-min session with the interactive robot were analyzed via Statistical Package for Social Sciences (SPSS) 11.5.

For studying specifics of the participants' interactions with the robotic cat, Pearson correlations (r) were used. Analysis of the group differences (based on age, gender, and culture) was performed both via Levene's test for equality of variances (a statistical measure F) and an independent sample t-test. The degrees of freedom are shown for both criteria (i.e., $t_{(29)}$ or $F_{(27)}$). Only outcomes with an alpha level less than 0.05 were considered for the interpretations. Distributions of the used variables were fairly symmetric and had no outliers.

The U.S. group (see Table 2) included nine persons with the mean age of 28.4 years, and seven persons with the mean age of 67.5 years. Sixty-seven percent of younger participants and 28% of older persons were females. The Japanese group included ten persons with the mean age of 21.6 years, and six persons with the mean age of 72.5 years. Ninety percent of participants in the younger group and 33% of older participants were females.

Table 2
Cross-Cultural Study Participants' Age and Gender

Groups by culture	N	Age (mean)	Gender (%)	
			Male	Female
USA				
Young participants (range 20 - 35)	9	28.4	34	67
Older participants (range 65 - 79)	7	67.5	72	28
JAPAN				
Young participants (range 20 - 33)	10	21.6	10	90
Older participants (range 65 – 78)	6	72.5	67	33
Groups by age				
Young participants (range 20 - 35)	19	25.3	21	79
Older participants (range 65 - 79)	13	69.8	69	31

Age and gender differences in person–robot interactions:

Older people enjoy it more than younger people when the robotic cat "meows" ($t_{(30)} = 3.2$, $p = 0.003$) and when the robotic cat listens if spoken to ($t_{(29)} = 2.3$, $p = 0.031$). With age, the evaluation of the interactive session as "interesting" and "exciting" progressed ($r = 0.40$, $p = 0.03$). Interestingly enough, the younger participants were the less active in tactile interactions with the cat, such as stroking its body, rubbing behind the ears, playing with the paws, tail, or ears, and stroking the back with their palm open (average $r = 0.55$, $p = 0.002$). Analysis of the past technological experience scale showed that younger participants use cellular phones, computers, and household devices more intensively then older adults and enjoy technology more in general (average $r = 0.58$, $p = 0.002$).

No differences between sexes were found on the subscale of tactile and manipulative interactions. However, males from both cultures more so than females like the cat's active behavior. Compared to the females, they enjoyed it more when the cat turned its head around, closed and opened its eyes, and changed its posture ($F_{(29)} = 9.57$, $p = 0.004$). The most marked gender difference was found for the item "I like when the cat opens and closes its eyes" ($F_{(30)} = 12.60$, $p = 0.001$). Males also enjoy a little bit more the action of stroking the cat's back with their palm open ($F_{(30)} = 5.60$, $p = 0.03$). Surprisingly, females enjoy it less when the cat cuddles ($F_{(29)} = 5.62$, $p = 0.002$) and moves its ears ($F_{(29)} = 5.12$, $p = 0.003$). Overall, males describe interactions with the cat NeCoRo as "exciting to play with" ($F_{(29)} = 9.72$, $p = 0.004$), whereas females tended to evaluate the cat as "boring to interact with" ($F_{(29)} = 9.78$, $p = 0.004$).

Cultural determinants of robot's behavior and character:

Cross-cultural specifics of interactive patterns: It seems that Americans enjoy touching the robotic cat a little bit more than the Japanese. Overall tactile interactions were more intensive for U.S. participants ($F_{(29)} = 4.03$, $p = 0.05$). The greatest cultural differentiation was found for the behavior from the tactile interaction scale indicated as "touching cat's body" ($F_{(29)} = 7.02$, $p = 0.01$). However, for other items on the tactile scale, no significant differences were found.

On the scale that evaluates the cat's behavior, cross-cultural specifics were established for the item "looking in the cat's eyes" ($F_{(30)} = 7.8$, $p = 0.009$). It seems that Japanese people do not like it when the cat looks at them. Americans like it a lot more than Japanese participants when the cat cuddles while being stroked ($F_{(29)} = 10.7$, $p = 0.003$). This feature has the most distinct cultural connotation. The second subsection of the instructor's evaluation, which measures overall satisfaction with the interactive session, shows that Americans in general consider interactions with the robotic cat more exciting and interesting ($F_{(29)} = 8.76$, $p = 0.006$).

Cross-cultural specifics of interactive patterns for younger adults: Some interesting results were obtained after the comparison of two groups (Japanese and American) of younger adults. Young Japanese adults have an extreme dislike for when a cat cuddles while they stroke it ($F_{(17)} = 12.0$, $p = 0.003$). The Americans liked it when a cat makes sounds when it moves, while the Japanese participants do not like it ($F_{(17)} = 5.30$, $p = 0.03$). Slight differences were found for the item "exciting to play with." Young Japanese participants were not as excited about playing with the robotic cat as their overseas counterparts ($F_{(17)} = 4.60$, $p = 0.04$). In general, the Japanese youngsters were less interested in interacting with the robotic cat than the American young people ($F_{(17)} = 5.80$, $p = 0.03$).

Influence of person's past experiences with real pets and modern technology on communication with the robotic agent:

Among the general sample, more than 50% of participants in both cultures admit that they adore pets. No age or sex differences were found for the item "I like pets." However, as expected, the degree of a person liking pets influences their style of interactions with the robotic cat. The more people like real pets, the higher score they have on a subscale of tactile interactions on such behaviors as rubbing behind the ears or stroking the back with their palm ($r = 0.37$, $p = 0.04$). Pet-lovers also evaluate NeCoRo as an exciting robot with which to play ($r = 0.47$, $p = 0.007$).

We also looked at how past experiences and interactions with real cats influenced the participants' communication with the cat NeCoRo. Those participants in both cultures who had rich experiences of interactions with real cats enjoyed more manipulative activities with the robotic cat, such as picking it up ($r = 0.45$, $p = 0.01$) and keeping on their lap ($r = 0.37$, $p = 0.03$). The more experience the participants had, the more they liked how the robotic cat cuddles ($r = 0.37$, $p = 0.04$).

Analyses of group differences showed that pet-lovers like the robotic cat's responses to touch ($F_{(27)} = 5.01$, $p = 0.03$). Participants with greater real pet experience are more likely to kiss the robotic cat ($F_{(29)} = 5.15$, $p = 0.03$). They also see the discrepancies between a real and artificial cat more clearly, indicating that NeCoRo is "heavy to pick up" ($F_{(29)} = 11.1$, $p = 0.002$) and that it produces "unnecessary noise" ($F_{(29)} = 20.3$, $p = 0.0001$). At the same time, those who show greater activity with real pets are more inclined to consider that the robot's behavior is very interesting to observe ($F_{(28)} = 4.86$, $p = 0.03$).

Experience with new technology, such as the use of a cellular phone, had the most distinct cultural influence. Japanese youngsters enjoy cell-phone applications far more than their American counterparts ($F_{(16)} = 26.76$, $p = 0.0001$).

Cross-cultural specifics of the interface between past experiences with a real pet and communication with the robotic creature:

American pet-lovers: With the American group, the degree of liking a real pet was associated with how the robotic cat moves its tail ($r = 0.72$, $p = 0.002$). Overall, Americans who love cats tend to use higher scores on scales evaluating NeCoRo's behavior and responses ($r = 0.54$, $p = 0.03$). They like it when the cat is active and interacting with them. However, those who indicate extensive past experience in communicating with real pets do not think that NeCoRo is good to touch ($r = -0.58$, $p = 0.02$).

Japanese pet-lovers: A slightly different scenario was encountered with the Japanese group. Those who love real pets tend to like the color of the NeCoRo cat ($r = 0.52$, $p = 0.02$). Japanese people with a greater amount of experience in interacting with real pets reported higher levels of enjoyment when interacting with the NeCoRo cat by stroking the cat's back with their palm ($r = 0.51$, $p = 0.04$), picking the cat up ($r = 0.60$, $p = 0.01$), and keeping the cat on their lap ($r = 0.53$, $p = 0.003$) more than those who had less experience with cats. Liking a real pet is associated with liking the robotic cat's cuddling in response to stroking ($r = 0.59$, $p = 0.001$).

Overall, American pet-lovers like picking up the robotic cat more than the Japanese pet-lovers ($F_{(21)} = 10.5$, $p = 0.004$). They enjoy keeping the cat on their lap ($F_{(21)} = 6.6$, $p = 0.01$) and turning the cat over ($F_{(20)} = 6.0$, $p = 0.002$) more as well. Also, Americans consider NeCoRo's character to be friendlier than the Japanese, who evaluated the robotic cat as a bit aloof ($F_{(21)} = 9.1$, $p = 0.007$).

2) Robotherapy for Persons With Cognitive Impairment: Relatives of elderly persons diagnosed with dementia and residing at nursing home special care unit were approached with the purpose of obtaining an informed consent. Nine of them agreed for their relative to participate in a study with the robotic cat NeCoRo. All participants were females with an average age of 90 years (ranging from 83 to 98 years). The mean score for the Global Deterioration Scale [54] (GDS), which is a single item assessing severity of age-related cognitive decline and Alzheimer's disease via a Lickert-type scale from one (no cognitive decline) to seven (late dementia or very severe cognitive decline), was 5.4 [with the range from four (moderate cognitive decline) to seven (late clinical phase with severe cognitive impairment)].

This study on persons with dementia was based on a controlled-condition experimental design involving a comparison of engagement responses to two different stimuli—the robotic cat NeCoRo and a plush cat toy [53]. The nine nursing home residents with different levels of cognitive impairment received two interactive sessions—one with the robotic cat and another one with the plush-toy cat—with a duration of 10 min each. At baseline (5 min before the session) as well as during the session, direct observations were conducted. Observations measured the quality and quantity of agitated behaviors and the expression of affect such as pleasure, interest, sadness, anxiety, and anger. The resident's engagement with the stimuli was measured in minutes. Intensity of manipulation with the plush toy or a robotic cat was assessed on a Lickert-type scale from one (lower score) to five (a higher score). Information regarding the person's past experiences with real cats was obtained from their family members.

Positive experiences of persons with dementia entertained by a robotic creature: The change in agitation from treatment to baseline was studied via a paired sample t-test. Results showed that the level of agitation decreased during the treatment phase. When the residents were involved with the plush cat, the level of agitation decreased significantly ($t_{(8)} = 2.5$, $p = 0.036$ and $t_{(8)} = 2.4$, $p = 0.046$ respectively). Engagement with the robotic cat also lowered the level of agitation in the expected direction, but this was not statistically significant ($p = 0.078$). Analysis of the data on affect revealed that during the sessions with the robotic cat there was a significant increase in pleasure ($t_{(8)} = 3.6$, $p = 0.007$) and in interest ($t_{(8)} = 2.7$, $p = 0.028$); with the plush toy, the increase of positive mood was in the same direction but not statistically significant ($p = 0.111$ for pleasure and $p = 0.052$ for interest). Control comparison of agitation and emotions at the baseline for the robotic cat versus plush cat sessions exposed no significant differences.

A correlation analysis was performed for the engagement parameters, indicators for the level of cognitive impairment, and the person's liking or disliking real cats in the past (before entering nursing home). For the robotic cat, the level of cognitive functioning was associated with the duration of engagement, so that persons with higher cognitive levels tended to spend more time with the robotic cat ($r = -0.67$, $p = 0.05$), whereas for the plush cat, cognitive functioning was associated with the intensity of manipulation, so that persons with higher cognitive levels manipulated the plush-toy cat more ($r = -0.73$, $p = 0.03$). Although correlations between a person's past liking of real cats and parameters of engagement did not reach significant levels, they were in the expected direction.

3) Individual Style of Person–Robot Communication: Case Studies: An analysis of person–robot communication has a wide spectrum of psychological implications. The case studies presented below (examples are extracted from a group of 40 people who reside in the Friendship Heights community), which were part of our project, illustrate how communication style and personal problems revealed themselves via interactions with the robotic creature [55].

Cases 1 and 2. Alice and Nancy: Two eight-year-old girls: Alice and Nancy are girls of the same age. Their interactions with the robotic cat NeCoRo named Max reveal individual differences in the manner of self-expression. During the 15-min session with Max, Alice started by cautiously touching and stroking the cat. However, soon she began to interact with the cat in a very friendly and caring way by creating gaming situations and expressing love and pleasure for their new partnership. Alice tried all possible ways of communicating with the robotic cat, except for verbal. At the end of the session she learned enough about the robot's skills to provoke the cat's responses at any time. Alice initiated interactions with the robot and actively involved the robotic cat in her games. At the same time, she was very sensitive and responsive to the robot's reactions and never tried to force the cat into any activities beyond its abilities. They got along very well. At the end of a session, Alice became so attached to the robotic cat, she began to rub her nose against Max's nose while looking into his eyes, lifted him in the air, and lovingly hugged Max and kissed him. Alice was an initiator and creator of the gaming situations, and she obviously felt pleasure and joy from interacting with the robot. However, a distinctive feature of Alice's interactions with the robotic cat was an absolute absence of verbal communication on one hand, and a display of a wide range of nonverbal behaviors with a rich variety of positive emotions on the other. Alice demonstrated high tactile as well as manipulative scores, but poor levels of verbal communication. Alice determined the robot's character as a friendly one and provided the following explanation of her choice: "Max is friendly because he responds to my touch. I like to play with him, stroke him, and watch how he responds to me."

Nancy chose a different strategy of interactions with the robotic cat. She was skeptical at the beginning and started her session with Max by rubbing behind his ears with two fingers. However, when Max responded to her touch by slightly moving his head, Nancy backed up and said, "It's weird! It's scary." Then for a long time she just stared at the robotic cat without any intention to touch him. She expressed nervousness by restlessly moving her legs. She was detached from the interaction and provided the following explanation by expressing verbal criticism (while trying to hide her fear of uncertainty in robot's behavior): "He is so boring! He probably does not like me. What am I supposed to do with him?" After a while she repeated her attempt to establish a communication with Max, this time with success. She picked the cat up, held him on her lap, stroked him with one or two fingers, and sometimes with an open palm. But her attention was shifting back and forth and she tried to talk about different subjects with the instructor while avoiding direct communication with the cat. Nancy demonstrated an ambivalent style of interaction with the robotic cat, which may indicate a fear of uncertainty and rejection.

Case 3. Rick: A 70-year-old man: Rick felt awkward in the presence of the robotic cat, as he was trying to act aloof. He started dialogue with the robotic cat with the following remarks: "I am not a cat person. But it does not matter for the research, right?" The instructor had to reassure him by saying that each person communicates with the robotic cat in one's own way. After this "introduction," Rick carried on a dialogue with the robot as if it were a real cat by asking questions: "You do not bite, do you? Are you aggressive? Do you have sharp teeth? Well! Dogs and cats constantly bite and scratch me. You would not bite me, would you?"

During the session, Rick never took the cat in his hands, and touched it only with one or two fingers. Rick constantly distracted himself by talking about or looking at other objects. He did not express any pleasure or joy while interacting with the robotic cat, but just "participated in research." Rick's slight initial interest manifested at the beginning of the session was quickly exhausted and in 5 min was replaced with indifference and boredom.

While indicating his interests after the session, Rick called himself an active technology user and emphasized that he had never had mutual relationships with any pets.

Case 4. David: A 76–year-old man: From the first minutes of the interactive session David was amazed by Max: "This is a robotic cat? Well, I should admit that this is a piece of art." He passionately grabbed the cat with two hands and started to stroke it with love and compassion. David was extremely curious about Max and enjoyed interactions with the robot very much. His communication with the artificial creature from the very beginning was personalized. David treated Max as if he were a real pet: "I am not afraid of you. You do not have teeth and I am aware of it." He accompanied the cat's meows by saying: "See, I can talk in your language. Meow! Meow!" David was excited when the cat responded to his touch: "Oh, you like this? Good boy!" David was trying to catch Max's attention by singing him songs, calling him "kitty, kitty" and rubbing under the cat's neck. David was under the impression that Max would interact with him like a real cat. David tried to pick the robot up by its front paws, but when Max refused to respond, David realized it, so he would not force the robotic cat to do something against its "will" or "ability." David created gaming situations for robotic pet by clapping above the table's surface while trying to provoke some new reactions, or by giving the cat cute names such as "pussy cat." Max was very interactive with David; the robotic cat was trying to stand up on his four legs and even made an attempt to stay on two back paws, but unfortunately almost fell sideways.

In sum, David tried a wide repertoire of verbal and nonverbal communications with the cat, expressed love and compassion for the robot, and enjoyed playing with it. Only a few exceptions that probably require further psychological analysis occurred. David did not call Max by his own name and never tried to turn Max over, pick up or hold the robot in the hands, or stroke its whiskers, ears, or tail.

VII. Robotic Psychology and Robotherapy: Conclusion on Experimental Studies

A. Cross-Cultural Study

The higher level of appeal of interacting with the robotic cat by older participants shows that this animal-like artificial creature meets their needs and is a more desirable companion for them than for the younger participants. This result confirms the intentions of the NeCoRo cat developers: to create a robotic pet who might be a partner, a friend, and a companion for the older person. Our data also show that intensity of past interactions with technology does not predict interest in the robot. Though young people receive more pleasure from technology in general, their evaluation of the interactive session with NeCoRo as exciting and interesting was lower than in older adults.

Preliminary results showed that past experience with real pets was positively associated with the intensity and variety of tactile communication with the robotic cat. The degree of liking real pets influenced the way people interact with the robotic cat. Experience with a real pet also influenced the evaluation of robotic pet features by participants. Presumably, participants were subconsciously comparing an artificial cat with a real one, naming heavy weight and unnecessary noise as unattractive features of NeCoRo.

Although pet-lovers in different cultures enjoy touching and manipulating the robotic cat, Americans have higher scores on both scales. The robotic cat's expressive behaviors (i.e., direct looking, cuddling) seem more enjoyable for American participants.

B. Robotherapy for Persons With Cognitive Impairment

Results show that persons with dementia can be engaged in interactions with a robotic creature. Both the robotic cat and the plush-toy cat produced similar effects on agitated behavior and expressed affect—the amount of manifested disruptive behaviors decreased and the amount of positive emotions increased during the treatment phase as compared to the baseline. The interactions with the robotic pet triggered such positive emotions as pleasure and interest. At the same time, persons with higher levels of cognitive impairment were engaged with the robotic cat for a shorter duration of time than those with higher levels of cognitive functioning. It is also interesting that even with the plush toy, which is lacking any interactive behaviors, the level of the intensity of manipulation was strongly associated with the level of deterioration—the more impaired the resident was, the more difficult it was to manipulate the plush toy.

C. Case Studies

A person's interaction with a robot has a diagnostic character. Individual manners of establishing relationships with artificial creatures reflect individual styles of self-expression and behavior. In particular, interactions with the robot serve as the mediator between the person's past communication and personal experiences in different situations, also reflecting an individual style in dealing with a task that involves a high degree of uncertainty.

VIII. Psychology-Oriented Robotics: Plan for the Future

A study on human–robot coexistence based upon robotic psychology and robotherapy has rapidly developed into the new interdisciplinary field of cyberanthropology that combines methods of cybernetics and humanities, engineering and biology, differential psychology and psychophysiology, information sciences, and aesthetics [56]–[58]. An analysis of robotic beings and their behavior from a psychological point of view opens new perspectives for theoretical and practical applications in both technological and social sciences.

Presented methodological and experimental results were focused on psychological effects produced by the "communication loop" between an interactive robotic agent and a participating person. Some general statements resulting from the experiment are as follows.

- People across gender, age and culture tend to perceive a robot who possesses a lifelike appearance as a friendly companion.
- Regardless of physical impairment and cognitive status, people are able to communicate with an artificial creature on a personal level.
- An interactive robotic creature triggers positive behaviors and emotions such as interest, involvement, pleasure, and joy in all studied groups (e.g., children of 5–12 years, elderly over 80; American, Russian, and Japanese), as well as individuals with special needs (e.g., coronary artery disease, sensory disintegration disorder, Alzheimer's disease, and attention deficit disorder).

The effectiveness of person–robot interactions in a psychological context is based upon productive compatibility between human beings and their artificial partners and can be achieved through:

- systematic study of individual needs and preferences as they relate to modern technology;
- friendly design and appealing appearance of the robotic creatures;
- adjustable behavioral configuration of a robot;
- multimodal interactive interface based on the open-loop principle that allows people to communicate with the robot on all levels (tactile–kinesthetic, sensory–motor, cognitive, emotional, and social).

As a new way of helping people, psychology-oriented robotics is aimed at: 1) the optimizing of artificial creatures functioning in human environments through the improvement of compatibility between people and robots and 2) the enhancement of personal well-being through the development of various coping skills mediated by technological tools.

Incorporating the elements of training, education, entertainment, and therapy into the person–robot communicative process leads to the development of advanced constructive models of "smart" interactive technology.

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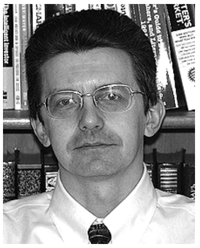

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