Robots Who Care:
Robotic Psychology and Robotherapy Approach

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Abstract

Authors offer a Robotic Psychology and Robotherapy concept based on a new paradigm in robotic sciences that emphasizes 'human-oriented' rather than 'mechano-centric' values of engineering design resulting in user-friendly appearance and increased interactivity of artificial creatures. Robotic Psychology focuses on studying compatibility between people and robotic creatures on sensory-motor, emotional, cognitive, and social levels. Robotherapy is defined as a framework of human–robot interactions aimed at the facilitating a person's positive experiences through technological tools in order to provide a platform for building new coping life skills. A multi–site project involving robotic cats, Max and Cleo serves as an example of how general principles of the Robotic Psychology and Robotherapy approach are applied to the analysis of individual and group differences in interactions between a 'caring' robot with advanced artificial intelligence and synthetic sensory feedback and elderly persons of different gender, mental status, and life experiences.

Introduction

The invention of the microchip brought new technological tools to the traditional field of care services. The unexpected rise of e-health applications, including telemedicine, virtual reality (VR) and robotics[1,2,3], rapidly formed their niche in the early 21-century medicine, clinical psychology, and psychotherapy. As of today, there are at least four major methods that can be distinguished in technology-mediated interventions:

- Virtual reality (VR techniques for treating anxiety, attention-deficit disorder, fear of flights, variety of phobias)
- Internet-based communication (tele-hypnosis, distant psychotherapy, therapy-related knowledge acquisition)
- Electronic games potentially ready for clinical application
- Interactions with embodied agents such as social and entertainment robots with different levels of artificial intelligence and synthetic sensory feedback.

Modern technological applications inspired both researchers and practitioners to create innovative methods to improve fact-based services for the elderly who feel lonely, depressed and under-stimulated. Interdisciplinary research based upon technological and psychological achievements lies at the foundation of the new, non-traditional area of robotics. This article concentrates on the use of interactive engaging robots as human companions analyzed through the newly developed concept of robotic psychology and therapy.

1. Robotic Psychology: Personal Dimension of Technology

A new paradigm in robotic sciences emphasizes 'human-oriented' rather than 'mechano-centric' values of engineering design resulting in user-friendly appearance and increased interactivity of artificial creatures.[4,5,6,7] The shift toward human values within technological processes mirrors the complexity of living beings. 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, abilities and coping strategies, robotic creatures also differ from each other. Robots' distinct 'individuality' manifests itself in the hardware design and software-based behavioral configurations. From a psychological point of view, personal robots are capable of playing a beneficial role of human companions, appearing as educators, entertainers, rehabilitation or medical assistants, and even psychological therapists. A technological evolution of robotic creatures developed their ability to interact with children and adults with a wide range of disabilities, and elderly persons with physical and cognitive impairments, and emotional and social problems. Human needs become a trigger point of new trend of research that concentrates of studying advantages and disadvantages of person-robots interactions including investigation of their compatibility.

INTERACTIVE ENGAGING ROBOT			PERSON	
Type	**Physical appearance**	**Behavioral configuration**	**Need**	**Benefit**
Social robots	Anthropomorphized appearance or animated form of real or fictional beings	Imitation of human facial expressions and complex gestures with social meaning or modeling basic emotional states and life-like behaviors	To provide company	Communication and companionship
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

Figure 1. Classification of Interactive Engaging Robots ('Caring' Robots) with Regard to Human Needs and Benefits

Presented above (see Figure 1) is a primary classification of 'caring' robots associated with the class of interactive engaging robots based upon such criteria as: (a) the purpose of a robot design as it relates to a particular human need, (b) a robot's behavioral configuration defined by the degree of freedom, (c) robo-IQ[8], and (d) the robot's physical properties manifested in their appearance. Robo-IQ is a quantitative index of robot's ability to navigate the world and interact with other beings. Robo-IQ is calculated through measures of 'smart' and 'caring' abilities including the level of artificial intelligence, a range of engaging modalities (sensory-motor, tactile-kinesthetic, and audio-visual), and interactivity based on the quality of a feedback. Robo-IQ, implemented through both hardware and software architecture, measures the complexity of autonomous intelligent and 'emotional' behavior which enables robot's efficient performance in the situations with high degree of uncertainty.

Robotic Psychology, or Robopsychology, is defined as a systematic study of compatibility between people and robotic creatures on sensory-motor, emotional, cognitive, and social levels[8]. Robotic Psychology focuses on differences and similarities 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 technology induced animation, resulting in a unique phenomenon described as a robot's 'personality.'

1.1. A Concept of Caring Robot as a Human Companion

A first major distinction that differentiates the class of interactive engaging robots from other groups is that 'caring' robots is elusively designed for the purpose of providing friendly companionship for the human. The concept of a robot as artificial beings who 'care' for people places the relationships between humans and robots into a psychosocial context. Literature analysis[4-9] and our data[13,14] suggest that several parameters depict a 'caring' robot as a good human companion:

- Life-like behavior of companion robot imitates behavior of human or animal triggering empathic responses from people
- Build-in sensors provide a companion robot with the ability to gain 'life experiences' while modeling emotional, cognitive, motor behaviors normally experienced by humans
- Companion robot able to communicate with the person on various levels such as tactile-kinesthetic, sensory, emotional, cognitive, and social – behavioral.

A second major distinction of caring robots is that it reflects a complex structure of the world including living and imaginary beings:

- Humanoids or anthropomorphic robots
- Robotic creatures imitating animals
- Artificial creatures imitating living beings other than humans or animals, or fictitious creatures.

Two distinct characteristics of interactive engaging robots make this class potentially valuable for psychological research and practice.

As of today, numerous caring robots equipped with tactile, audio, and visual sensors and different levels of robo-IQ navigate the human world or are ready to leave the labs. The well-known examples are anthropomorphic robots Cog and Kismet; Doc Beardsley and Nursebot Pearl; intelligent humanoids AMI, HERMES and ASIMO; the automated doll My Real Baby; the robotic cats Tama and NeCoRo, the robotic dog AIBO, and a therapeutic robotic seal Paro. While practitioners and researchers gradually realize that as the era of person-robot co-existence is already in progress, theoretical and applied justification has to be developed to embrace and analyze the epistemology and phenomenology of an already diverse robo-population including criteria for constructive match robots and persons.

It is no coincidence that 'caring' robots became the subject of a new field of study which emphasized the psychological, social, and therapeutic importance [8, 9] of human – robot interaction. 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, personal preferences, psychological profile, etc.) manifested through human – robot interactions.

Experimental results communication with the 'caring' robots presented in the following sections illustrate a wide range of human reactions emerging from interaction with the robotic cats NeCoRo named Max and Cleo.

2. Robotherapy As Technology-Mediated Psychosocial Intervention

Robotherapy represents an innovative technology-mediated therapy that is defined as a framework of human–robotic creature interactions aimed at the reconstruction of a person's negative experiences through the development of efficient robot-mediated coping strategies in order to provide a platform for building new positive life skills.[5] In a broader sense, the innovative concept of robotherapy offers methodological and experimental justification for the use of non–pharmacological interventions based on stimulation, assistance, and rehabilitation techniques for people with physical and cognitive impairments, persons with special needs, or psychological problems. As technology-mediated and oriented psychologically, the goal of robotherapy in studying of 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) designing individually–tailored psychosocial interventions based upon people's needs and preferences.

Therefore, the effectiveness of robotherapy is influenced by both individual experiences, including current needs and preferences, and a 'caring' robot's physical features and behavioral configurations that provide for intensity of stimulations and responses.

2.1. Engaging Interactive Robots as Mediators in Robotherapy

The many functions of a 'caring' robot are being dramatically shifted from roles in service and entertainment domains to originally exclusive human occupations, such as supportive care, treatment, therapy, and companionship. The most important change in application, although somewhat unexpected for many professionals, is that advanced artificial creatures with high robo-IQ and synthetic sensory systems can be effectively used as intervention in a form of:

- Mediators in person-to-person communication
- Interactive devices for training and development of certain individual and group skills
- Tools for guided physical and mental stimulation
- Human companions in special situations and life circumstances.

Those basic features lie at the foundation of the methodology on robotherapy where a robot plays the role of a therapeutic agent communicating with a person in different modes and promoting physical/sensory-motor activities, cognitive and emotional stimulation, and – most importantly – providing an individual with psychological benefits (i.e., sense of control, independence, and self-efficacy)(see Figure 2).

As it was emphasized by the cybernetics pioneer Norbert Wiener, the ability to resist entropy by modifying behavioral configurations on the basis of past experiences and sensory feedback is a major function of sophisticated communicative machines as well as higher living organisms.[10]

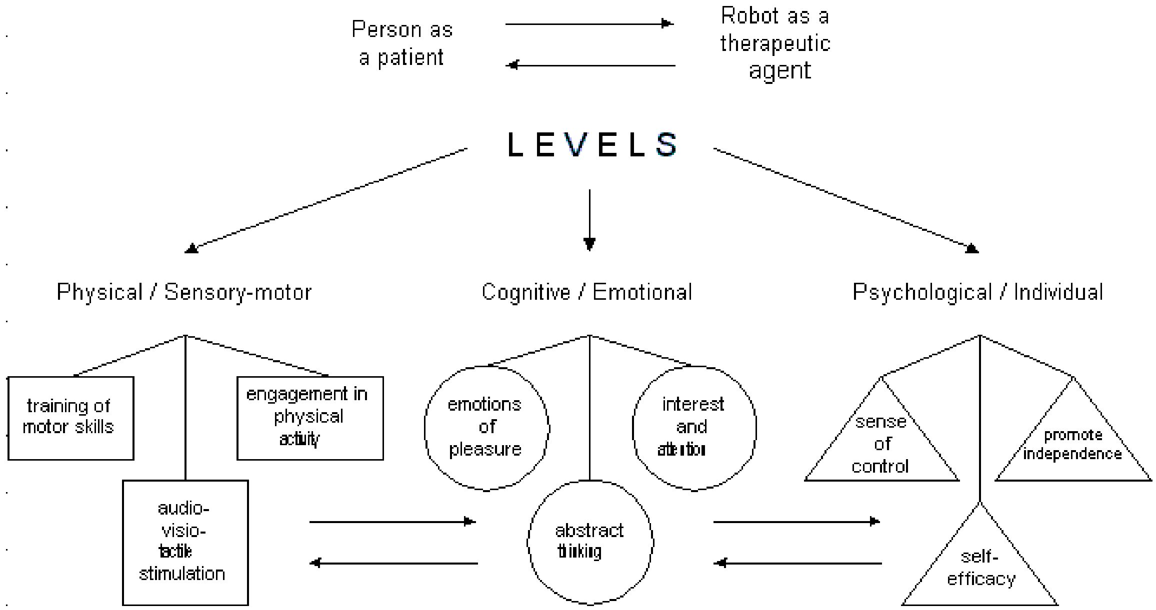

Figure 2. Communication between a person and a robot as a therapeutic agent (a Complex Interactive Systems approach[11])

3. Experiments In Robotic Psychology And Robotherapy

A multi–site project involving robotic cats Max and Cleo serves as an example of how general principles of the Robotic Psychology and Robotherapy approach are applied to the analysis of individual and group differences in interactions between a 'caring' robot with advanced artificial intelligence and synthetic sensory feedback and elderly persons of different gender, culture, mental and physical status, and life experiences.

3.1. Robotic Cat as Psychosocial Intervention For Elderly

The robotic cat NeCoRo (see Figure 3 and 4), manufactured by the Omron Corporation (Japan), is alternatively called a mental health robot. 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. The following characteristics create a 'caring effect' of robot NeCoRo's personality:

- Responsiveness to human voice, movement, and touch
- Adjustability of robot's 'personality' to the owner's interactive style
- Acknowledging of its name when called
- Feline appearance due to synthetic fur that provides a 'natural' feel creating a simulation of petting a real-life cat

In order to analyze how people perceive and interact with robots of different kinds, a unified assessment – Libin Multidimensional Person - Robot Interactions Scale (LMPR) – also known as PRCIS (Person-Robot Complex Interactive Scale)[12,16] – was designed.

Figure 3. Ms. S. enjoying the company of the robotic cat Cleo

Each pattern reflected on the scale 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 variety of person–robot interactions was grouped into four universal modes or dimensions such as verbal, nonverbal, emotional and animated. Each mode was characterized in terms of *intensity of interactions* on a Lickert type scale from 1 (lowest score) to 5(highest score). LMPR includes the following scales and subscales:

- A. Non-verbal communication scale
  - A-1. Tactile subscale
  - A-2. Manipulation subscale
- B. Verbal communication scale
- C. Animated interactions scale
- D. Emotional display scale
  - D-1. Positive emotional display
  - D-2. Negative emotional display

Those LMPR's crosscutting parameters allow the modification of a universal assessment of person-robot interactions by adjusting the scale to robot's specific features, e.g. humanoid, robotic pet or life-like 'dream creature'. For example, in presented study a scale was modified to measure a person – robotic cat interactions resulting in a version LMPR–Pet.

A. Non-verbal communication scale

It describes tactile and manipulative characteristics of person's interactions with the robotic pet.
A-1.Tactile subscale takes into account the specifics of a participant's tactile behavior such as touching a cat's body with one – two fingers or with the palm open; stroking cat's paws, tail and ears or playing with them. This subscale also indicates if the participant touches the cat nose-to-nose or does not touch a robot at all.
A-2.Manipulation subscale captures specific components of participant's manipulative behavior, for instance, whether participant shakes cat's paw, holds robo-toy or picks it up, puts robotic cat on the lap, hugs it or kisses.

B. Verbal communication scale

This scale measures whether a participant interacts with the robot through voice. Also, it differentiates between types of verbal behavior such as direct orders (i.e., Sit down! Don't do it!) or friendly engagement commands (i.e., Come to me, please!). The scale indicates whether a participant expresses verbal approval (i.e., Good boy! Very good!) or disapproval (i.e., You are bad! Shame on you!); talks with robot in personalized way (i.e., What a good boy you are!) and calls robo-toy by its name (i.e., Max! Maxy, look at me!); keeps up with a conversation (i.e., Do you like to play with me? – Yes, you do, don't you?!); or reacts verbally only when the robot become active.

C. Animated interactions scale

This animated interactions scale assesses how a participant perceives the robotic pet and treats it. This scale specifies whether a participant interacts with the robot in a personalized way and treats it like a real pet, or rather a technological device. The following behaviors are identified as animated interactions: participant looks directly into robotic pet's eyes or uses different objects to trigger response of the robot; cares about robot by performing as if activities such as feeding, cradling or putting robotic pet asleep. This scale takes into account whether the participant creates gaming situations by developing new ways of interacting with robot, for instance, by giving it cute names, such as 'Sleepy-head', or using greetings (i.e., Hello!), excuses (i.e., Sorry! I didn't mean it!), farewells (i.e., Good bye! See you soon!), and expressions of his/her feelings toward NeCoRo (i.e., Don't be angry with me! I like you!). The animated interaction scale also measures negative manifestations, i.e., hits or punches.

D. Emotional display scale

This scale deals with the participant's positive and negative emotional responses to the robot's behavior. Emotions included in this subscale differ by the intensity and specifics of their manifestation.
D-1.Negative display subscale shows whether the participant is disturbed by the robot presence, or not. Items identify if a participant is nervous, afraid of the robot or frustrated by its presence, ignores the robotic pet or expresses anger toward it.
D-2.Positive display subscale focuses on constructive emotional reactions of the participant. This subscale describes a wide range of positive emotions from curiosity to excitement.
Scale items were developed as a result of direct observations and literature analysis on human–robot communication. After developing a primary structure, observations were recorded on video and later examined by two independent evaluators. Inter-rater reliabilities for observations averaged 0.92. Data and experimental profiles were studied further with inferential statistics and content analysis.

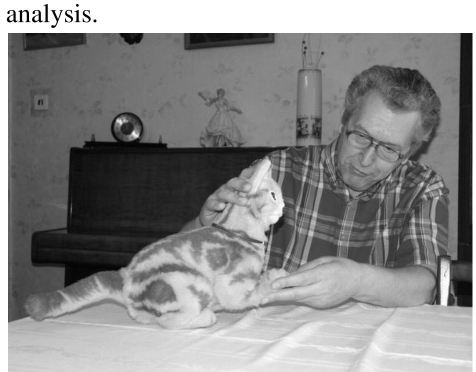

Figure 4. Mr. L. greets the robot Cleo by shaking 'hands' with it

3.2. Sample And Methods

Sample

A Robotic Psychology and Robotherapy project was initiated and coordinated through the Institute of Robotic Psychology and Robotherapy (see www.robotherapy.org) at a non-profit organization, CyberAnthropology Research, Inc., Chevy Chase, MD.

Study 1 involved 50 individuals of both genders, who formed two age groups – young people ranging in age from 16 to 25 years (90% females), and elderly persons with the age range from 68 to 81 years (60% females). Participants had different experiences with live pets and modern technology.

Study 2 was conducted at special Alzheimer's care units of a nursing home and at the Brighton Gardens assisted living facility at Chevy Chase.[16] 14 elderly persons (mean age of 78 years) with diagnosed dementia were involved in controlled study aimed at comparison of residents' responses to a robotic cat and a placebo intervention – a plush toy cat.

Method

Research procedure was standardized across all studies, in healthy and impaired populations. All sessions were videotaped for the purposes of inter-rater reliability and further content analysis. 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–minute 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 LMPR–Pet, Part 1 (Instructor's observational assessment). Observations were performed twice – during the first and the last three minutes of the session. A second instructor's evaluation was performed via LMPR–Pet, Part 2 (Instructor's overall evaluation) that 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 LMPR–Pet, Part 3 (Participant's evaluation of new experiences). The participant's past experiences with live pets and modern technologies were evaluated via LMPR–Pet, Part 4 (Participant's past experiences).

In **Study 1** responses to and perception of the robotic cat of older participants were compared to those of younger persons. The following hypothesis were evaluated:

a. Engaging interventions via the therapeutic robotic cat will be associated with a greater amount of positive responses in older people in comparison to younger participants due the greater need of elderly in companionship.
b. Tactile interactions will be more significant for elderly persons in comparison to younger people.
c. The amount of past experiences with technology will not influence the positive outcome and the quality of engagement with the robotic cat in older participants.

In **Study 2** elderly residents received in a randomized order one session with the robotic cat and one with the plush cat (see Figure 5). Residents manifested high level of cognitive impairment (5.4 out of 7 on the Global Deterioration Scale).[17] The following hypothesis were evaluated:

a. Interactive therapeutic intervention via the robotic cat will trigger more positive affect such as interest and pleasure in comparison to the non-interactive plush toy in persons with cognitive impairment.

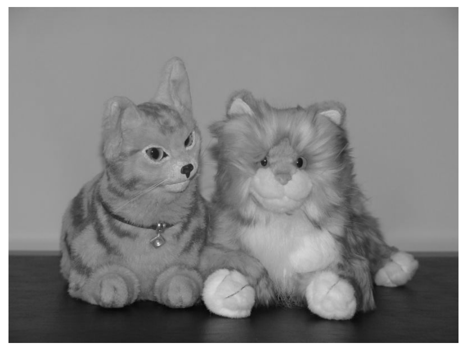

Figure 5. Robotic cat Cleo (on the left) and plush toy cat Matilda (on the right) – as psychosocial intervention for elderly persons with dementia

Various aspects of residents' positive and negative affect, as well as their interactions with the robot and a plush toy, were assessed through direct observations by trained research assistants.

3.3. Study Results

Study 1. Older people's perception of and interactions with the 'caring' robot

Results showed that older persons tend to evaluate an interactive robotic creature as friendly and pleasant regardless of their past experiences with technology and real pets.

In comparison to young people (mean age 21 years, N=21), older persons (mean age 73 years, N=29) were more appreciative of the robot's interactive features such as real-life imitating nonverbal behaviors and responsiveness to the tactile stimulation.

Although the analysis of the past technological experience showed that younger participants are much more sophisticated in using high-tech devices (e.g., cellular phones, computers and household electronics) and describe themselves as 'techno-funs' (t_{46} = 3.4, p = 0.002), older persons found a sessions with the interactive robot more exciting and joyful (t_{46} = 2.2, p = 0.035).

Older participants enjoyed it more than younger people when the robotic cat turned its head around (t_{46} = 2.1, p = 0.039), moved its tail (t_{46}= 3.2, p = 0.002), and listened if spoken to (t_{46} = 2.2, p = 0.03).

Interestingly enough, the older people were more responsive to cat's activities, for instance, they liked when cat closes and opens its eyes, changes posture and starches its paw (measured as a combined score on cat's behavior t_{46} = 2.2, p = 0.035). In comparison to younger participants, older persons emphasized that the robotic cat is 'good to touch' (t_{46} = 2.3, p = 0.029) proving the importance of tactile component of robot's engagement quality.

Study 2. Engaging therapeutic robotic cat as a technology-mediated intervention for persons with dementia

Study, which compared the benefits of a robotic cat and a plush toy cat as interventions for elderly persons with dementia showed that persons with severe dementia benefit from engagement with a robotic pet more than with interactions with a plush toy. Even so in comparison to baseline both interventions - mediated by the robotic cat and by the plush-toy cat managed to decrease the amount of manifested verbal and physical disruptive behaviors and increase the amount of positive emotions during treatment phase, the robotic cat Max triggered more positive emotions. Particularly during intervention with Max was significantly increased pleasure (t_{14} = 2.2, p = 0.031), and interest (t_{14} = 2.4, p = 0.022).

Differences also were found in time of engagement the with robotic cat between persons with high and low levels of cognitive impairment. Persons with lower levels of cognitive impairment were engaged with the robot cat for a longer duration of time.

Conclusion

Our findings from the presented and previous research [13,14,15], aimed at the psychological examination of human reactions emerging from communication with an artificial creature imitating an animal's behavior (i.e., the robotic cat NeCoRo), showed that:

- Persons across gender, age and culture tend to perceive life-like robots with empathic appearance, artificial intelligence and sensory feedback as caring companions rather then technological devises
- Clinical, as well as healthy population can benefit from interactions with the friendly robotic creature that is able to provide positive stimulation at various levels – from tactile to social
- Regardless of technological experiences elderly persons maintain a positive attitude toward the 'caring' robot, enjoy interacting with it, and appreciate their engaging qualities more than younger people
- A comparison of psychosocial intervention involving 'caring' robots to the non-interactive treatment method emphasized the significance of interactivity in creating positive therapeutic outcome

As our data confirmed, the 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 robotic cat NeCoRo as exciting and interesting was lower than in older adults. The higher level of appeal of interacting with a robot 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 that might be a partner, a friend, and a companion for the older person.

Presented methodological and experimental results illustrate psychological and therapeutic effects produced by the 'communication loop' between an interactive robotic agent and a participating person. An analysis of robotic beings and their behavior from a psychological point of view opens new perspectives for theoretical and practical applications in both health care research and the caregiving practice.

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