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ROBOTIC AFFECTIVE ABILITIES

Abstract

Within both popular media and (some) scientific contexts, affective and 'emotional' machines are assumed to already exist. The aim of this paper is to draw attention to some of the key conceptual and theoretical issues raised by the ostensible affectivity. My investigation starts with three robotic encounters: a robot arm, the first (according to media) 'emotional' robot, Pepper, and Mako, a robotic cat. To make sense of affectivity in these encounters, I discuss emotion theoretical implications for affectivity in human-machine-interaction. Which theories have been implemented in the creation of the encountered robots? Being aware that in any given robot, there is no strict implementation of one single emotion theory, I will focus on two commonly used emotion theories: Russell and Mehrabian's Three-Factor Theory of Emotion (the computational models derived from that theory are known as PAD models) and Ekman's Basic Emotion Theory. An alternative way to approach affectivity in artificial systems is the Relational Approach of Damiano et al. which emphasizes human-robot-interaction in social robotics. In considering this alternative I also raise questions about the possibility of affectivity in robot-robot-relations.

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Making sense of encounters with ‘emotional’ robots

At GV Lab in Tokyo, I met a robot arm that was equipped with a PAD emotion program combining the values of pleasure, arousal, and dominance to constitute an emotion that is expressed by a movement. Through interaction via different sensors, the robot executed different behaviors. If, for instance, I entered the robot’s ‘personal space’, as detected by a distance sensor, the robot executed an ‘emotional’ movement, as you can see in the image below:

Figure 1: Robot arm. Source: https://www.youtube.com/watch?v=q1DO4PBSA6M&feature=youtu.be.

I encountered the humanoid robot ‘Pepper’ in a shopping mall: it was standing in the corner, overwhelmed by ordinary noise. In the media, Pepper has been advertised as “the world’s first emotional robot” (Singh). This doesn’t seem very convincing. Most of the time, if there are no technical problems, passers-by did not pay attention to it. It did not seem to me that Pepper has much emotionality that humans typically react to. Perhaps Pepper would have been more interesting if it would have raised its voice or just gone somewhere else to avoid being ignored. Contrary to the robot arm, as you can see in the pictures, Pepper is a humanoid robot that has a face, changes its voice, and so on. Its outer appearance is intended to be cute and to evoke positive emotions.

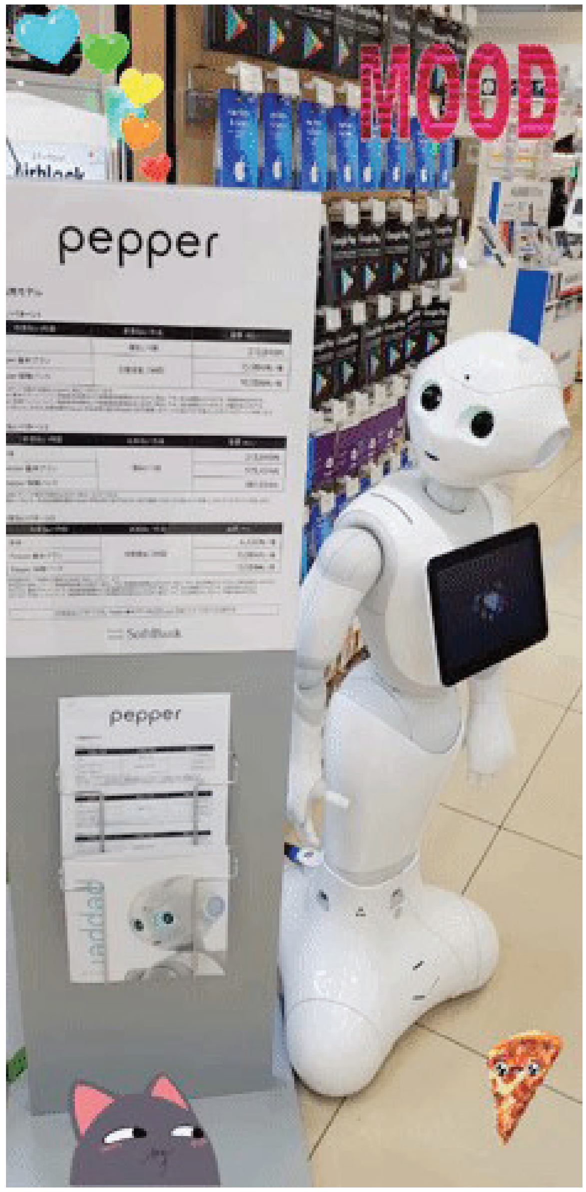

Figure 2: Pepper, emotional robot? Image by author.

Finally, I encountered Mako, the robot cat that I built at GV Lab in order to learn first-hand what machinic affectivity, and building a machine in general is all about. When does the machine start to interact, to be a robot, and to be affective? Mako is an Arduino-based small device equipped with distance and touch sensors for interaction. Moreover, it can express itself: by text through an LED display, by movement through a servo motor, and by noise through a piezo buzzer. It has neither emotion programing running, nor a capacity for changing facial expression.

Thus, it is a very basic robot. Nevertheless, it elicited confusion in humans that were not due to any malfunction. First the display says the neutral but welcoming message "what a nice day", then if the human approaches, the messages "touch me" and "do not approach" are shown; and if the human touches, the robot expresses a loud piezo beep and the message "go away".

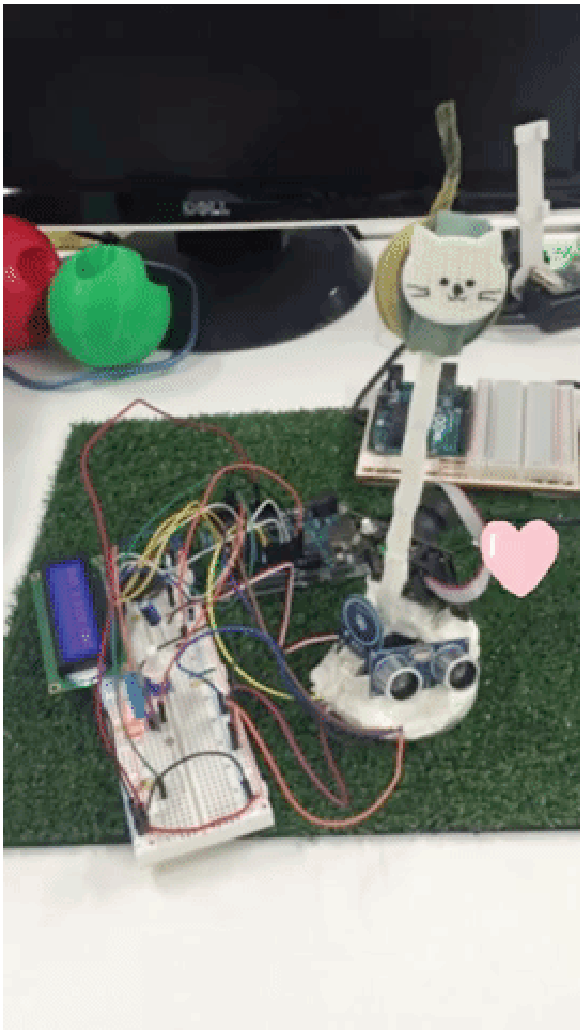

Figure 3: Mako, robotic cat. Image by author.

What was going on in these encounters? Various kinds of affectivity!

Besides everyone's own feeling of and for affectivity, there exists a variety of definitions for affective phenomena in living beings that one can choose from, making the phenomena hard to grasp. To follow the works of Colombetti, Deonna and Teroni, I use the notion of 'affectivity' to subsume phenomena like emotions, feelings, moods, primordial affectivity, sentiments, or affect.

The various definitions of affective phenomena in living beings come with different theoretical frameworks. In philosophy and psychology, these are notably emotion theories, each emphasizing different aspects of emotions. For instance, take the distinction between non-cognitivist and cognitivist emotion theories: When William James writes about emotion, he means the occurring bodily changes and their felt experience. For him, emotions without a bodily component are "cold" mental states (James 189). In contrast to this, Martha Nussbaum claims that emotions are cognitive "judgments of value" and the possibly occurring bodily changes are just their byproduct through physically imitating the cognitive processes (Nussbaum 194). These theories exemplify antagonisms and exclusions: Nussbaum's theory is far from an embodied perspective and excludes animals and children up to a certain age. 'James' theory' (or the 'James-Lange theory' that was later developed) would possibly be difficult to apply on systems that do not have bodies of flesh and blood. This example emphasizes that there is no uncontroversial definition of emotion or affective phenomena in living beings. In other disciplines, affective phenomena in artificial systems have been studied extensively (e. g. Suchman, Picard, Dautenhahn et al., Marsella et al., Boden).

When we look at robots and engineered applications, we often find emotions – machines modeled over emotional expressions, emotions evoked in humans through human-machine-interaction, and even emotional robots. Due to the lack of consensus regarding the definition of emotion, from an emotion-theoretical perspective, the theoretical basis of machinic emotional abilities has to be based on a working definition. For several years now, in disciplines like Affective Computing and Social Robotics, computer scientists and roboticists have applied (mostly psychological) emotion theories (e. g. Ekman and Friesen, Russell and Mehrabian), and taken emotion theories as a foundation of their programming and engineering (e. g. Bennett and Šabanović, Rincon-Ardila et al.). With no clear definition of what an emotion is, however, it is difficult to choose which theoretical framework to take and how to translate the (more or less) wordy theories into numbers. Besides, although there are many different theories of emotion and affectivity, most emotional programs and machines depend on just a few theories that are limited in describing emotions in general. Thus, what is this thing called emotion that in the end comes out of the machines?

In this paper, I reflect upon the emotion theoretical implications to affectivity in human-machine-interaction, having an academic background in practice-oriented philosophy and a practice in creatively exploring technology. I will briefly introduce two of the commonly used emotion theories that here shape the emotion theoretical discourse from the Western tradition: Russell and Mehrabian's Three-Factor Theory of Emotion (the computational models derived from that theory are known as PAD models) and Ekman's Basic Emotion Theory. My goal in this text is not to provide an exhaustive overview or detailed analyses of either emotion theories/models or artificial systems that include affective abilities. Rather, my goal is to raise questions and initiate discussion about the application of emotion theory to robots and the complexities of assessing the ostensible affectivity of robots.

During the three encounters I described above, I was confronted with three different ways of modeling affective abilities into machines: internal, external, and relational (Damiano et al. 8). As shown in the chart below, each way of modeling comprises several features I experienced during my encounters with the robots.

<table>
<tr><th>Perceivable / external</th><th>Invisible / internal</th><th>From the relation</th></tr>
<tr><td>Face (Pepper, Mako)</td><td rowspan="5">Program that serves as a regulation mechanism (PAD emotion model in the robot arm, Pepper depending on the program that is running)</td><td rowspan="2">Reciprocal affective interaction (Pepper smiles and I smile back)</td></tr>
<tr><td>Sound (Mako: piezo, Pepper: voice)</td></tr>
<tr><td>Blinking light (robot arm, Pepper)</td><td rowspan="3">Human affective interaction on a meta-level (I am amused when the cat robot exhibits contradictory behavior, I am happy when my guess for the "emotion" of the robot arm is the same word as what is displayed on the screen, and I am heavily annoyed when I hear Pepper's voice</td></tr>
<tr><td>Words, pictures (Mako: display, Pepper: tablet)</td></tr>
<tr><td>Movement (all three of them)</td></tr>
<tr><td>Basis: Ekman's Basic Emotion Theory (BET)</td><td>Basis: Russell's and Mehrabian's Three-Factor Theory of Emotion (PAD)</td><td>Can be explained through the relational approach with examples from Human-Robot-Interaction</td></tr>
</table>

Emotion theories as bases for emotion models

If the outer appearance of a machine includes emotional features, for instance displayed emotions, or emotion recognition technology, the work of Ekman and his colleagues is typically used as the theoretical basis (e. g. Bennett and Šabanović). In 1976, Ekman and Friesen provided a system to divide facial movements into "action units", which can be a movement of one or more muscles (and one muscle can be part of more than one action unit). Ekman, Friesen and their colleagues isolated each muscle movement in their own faces and observed video recordings and photographs in order to make sure that every facial expression consisting of one or more action units is unique. They called the resulting catalogue of facial expressions 'Facial Action Coding System' (FACS). Moreover, Ekman continued the ideas of Darwin with his work on basic emotions: over many years and several studies, he identified six basic emotions (happiness, surprise, fear, anger, disgust, contempt) that are expressed by unique facial expressions. According to Ekman's studies, humans from various cultural backgrounds can equally identify "at least five" of these six emotions (Ekman 551).

If a machine includes non-visible emotional features like regulative mechanisms that consider the environmental input through sensors and human-machine-interaction or internal changes, such as changes in temperature or the former emotional state, the Three-Factor Theory of Emotion is often used as the theoretical basis (e. g. Rincon Ardila et al.). This theory is sometimes better known as 'Pleasure-Arousal-Dominance' (or PAD). For Russell and Mehrabian, emotions can be captured and described in terms of pleasure, arousal, and dominance. Depending on the numerical value of each of the three dimensions, they form or explain a different emotion. The statistical methods used and the resulting significance of the theory is a topic open for further discussion. This theory, however, has been further developed in various ways since 1977, with Russell's 'Core Affect Theory' as its most popular contemporary spin-off. Today, PAD is still popular when equipping robots and virtual characters with emotions. For this, the PAD values are mapped as vectors in a three-dimensional space. Thus, an emotion program can be coded and added to the robot's other programs in the operating system. Depending on external or internal stimuli, for instance through incoming data from an ultrasonic distance sensor, the robot's emotion changes internally and produces, depending on its physical features, an emotional behavior as outcome (e.g. Rincon Ardila et al.).

A we have seen, in robotics-influenced emotion research, the external/social/expressive (see the BET example) and internal/individual/regulative aspects of emotion (see the PAD example) are distinct. Damiano et al. discuss this critically. External emotional features are often referred to as simulations of emotions, whereas an internal emotion generating mechanism (as in emotion models) would lead to genuine emotions. Therefore, these two distinct ways of creating affective abilities have also been rated as true/ eal vs. false/fake emotions (Damiano et al. 8). According to these verbal distinctions, it seems preferable to have regulative emotion mechanisms rather than visible emotional expressions — but why? Because this could provide a real-world-correlate to our imagination?

As Damiano and Dumouchel point out, this way of thinking is deeply Cartesian and exclusive (Damiano and Dumouchel 6). The phenomenon of emotion is split up into a Cartesian construct that is related to one matter, either ‘body’ or ‘soul’, which reflects modeling on the ‘outside’ or ‘inside’. Besides, the binary distinctions are in some cases not comprehensible (e.g. the true/false rating: how can an attempt to model affective abilities into artificial systems be ‘true’ or ‘false’?) and seem to be misleading. How could we tell which human emotion is real or fake, if we go beyond evolutionary or basic emotions that are necessary for survival? What if we look at ‘higher’ or social emotions? In these cases, we could possibly measure whether the person smiling at us is smiling with a Duchenne smile – or possibly, we cannot detect anything in the emotions of others and have to trust on what the person reports verbally about their emotion. Emotions can surely be ‘artificial’ also in humans (Stephan 310) in the sense of true/ eal vs. false/fake.

Moreover, the distinction between external and internal affective features of a robot goes against understanding it as an integral agent. Of course, the possible behavior range of robots is much less extensive than the human behavioral range, but at least in the intended interaction, the robot is an integral agent within its individual limits.

With an approach that focuses on interaction and relation between interacting systems, Damiano et al. suggest one way to make the binary distinctions between external and internal emotional features obsolete. At the same time, they do not exclude mechanical systems of a certain complexity from the possibility of having emotions. According to Damiano et al., interacting agents do not simply exchange

> *information about their supposedly pre-defined and individual emotional states, [they rather] mutually define— co-determine — their emotions during their ongoing interactions. […] [This view] requires us to abandon the traditional philosophical understanding of emotions as events that are individually, internally, and thus covertly generated, and that then we can expressively communicate to others — i.e., the very conception of emotions which legitimates robotics to distinguish between the internal and the external aspects of emotions and empathy (Damiano et al. 8).*

They call this approach a “relational conception of emotions”.

In this theory, affective phenomena can emerge from a relation that includes living beings or social robots, everyone and everything that is no (mere) tool and capable of interaction. This could happen in an interaction with Mako, the robot arm, or Pepper, depending on the properties of the relation between the robot and the interacting agent. Thus, if we imagine a human-robot interaction involving one human being and one robot, we have to think about three aspects of affectivity: What is going on affectively in the human during the interaction with the robot? What is going on affectively in the robot during the interaction with the human? What is emerging affectively from the relation and what does this do to the respective interaction partner? This holds also for interactions of (two or more) living beings and interactions of living beings and non-living entities. What about a robot-robot relation?

Affectivity in a robot-robot relation

A good example for both thinking machines as more than mere tools and machinic affectivity among machines is the installation *Nintendogs* of the artist Fabian Kühfuß. His installation captures perfectly the fascination (coming from science fiction) and absurdity (coming from scientific reality) of the question of whether a robot can have genuine emotions that go beyond sharp definitions or are more than the intended outcome of a relation. The artist combines a Nintendo DS console that runs the game *Nintendogs* with a motorized device that moves the console so that a pencil can touch the virtual dogs.

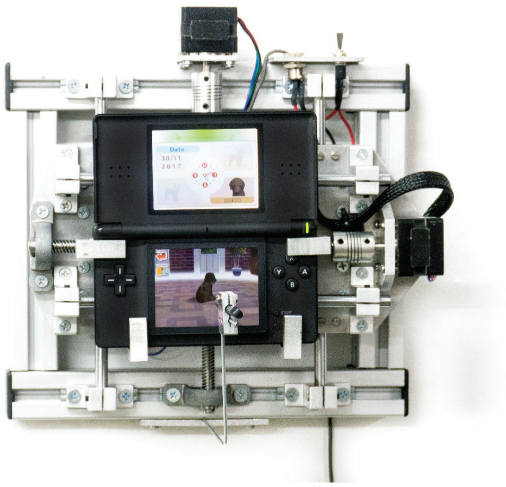

Figure 4: Fabian Kühfuß, *Nintendogs* (2017). Courtesy of the artist.

The purpose of this game is to raise and educate a baby pet dog. One of the possible actions is to stroke the dog, usually an affective action between two living beings. In his installation, Kühfuß transfers this action into a robot-robot-relation. This work raises at least two questions: ‘Can machines have leisure activities, too?’ and ‘What is machinic affectivity?’.

For the virtual dog, it does not make any difference who or what strokes it. For the motorized device, it makes no difference what it touches with the attached touch-pen. In both cases, the result is the same: the dog is stroked, the touch-pen touches. For playing the whole game, however, the machine would need more features that enable it to execute all the other necessary steps. Does the stroked virtual dog ‘feel’ good within its affective spectrum? Intuition is, however, that the human interpretation adds the specific affectively loaded meaning to this scenario.

What can this example tell us from a relational point of view? There clearly is an interaction between two machines. Plus, there is a human observer that does not take part in the interaction. Is there, however, something affective going on between the Nintendo DS and the touch-pen device? Affective in the sense typically applied to living beings? Affective in the sense of other possibly affective entities? Moreover, who or what is feeling something in this relation? Is this even important, as we cannot always see or detect what other human beings feel or if they are able to feel an emotion at all?

In any case, in the *Nintendogs* example, tasks and goals have been fulfilled successfully. The touch-pen device fulfilled its task to touch the display where it could perceive the puppy (thus, it stroked). The puppy displayed the behavior the game designers and programmers intended for the case after having been stroked. The human observer enjoyed and interpreted the artwork.

Affectivity ≠ affectivity

There is obviously an affective difference between artificial systems and humans. The difference becomes, for instance, evident in the spontaneity and goal-orientation of the interacting agents and their emotion range that still clearly separates machinic affective abilities from those of living beings. There is something interesting about confusing behavior, reacting not as expected, not creating the ‘perfect’, goal-oriented, faultlessly designed user experience. It creates some other kind of relation where humans need to engage in another way because they are somehow challenged. Moreover, there is something interesting (and relieving) about not being useful, not having to be useful, not needing to serve a certain purpose, not being instrumentalized, like machines always are, because they are built to serve as tools, even if social robots have an ambiguous status (Damiano and Dumouchel 2, 3).

Moreover, in these examples, my own reactions to the robot's affective abilities were, besides some aspects of a reciprocal relation, more like meta-reactions to the machinic affective abilities. For instance, if Mako tells me "Go away!" after having told me to approach, I think this is rather funny. Besides, it is not boring (at least the first time you try the robot out), because it reacts not as expected and does not fulfill any higher purpose (that we, maybe, expect in a machine). If Mako was a human being, I would be irritated, confused, or even concerned. So was the woman who tried Mako out during a lab visit – she was irritated and confused by Mako's behavior.

However, if we aim to facilitate understanding and cooperation between roboticists, computer scientists, psychologists, and the humanities, we should be open to adding definitions and theories from technological fields to the many (imperfect) emotion theories we already debate in philosophy, psychology, and other disciplines. If we want to understand the work roboticists and computer scientists are doing, and if we aim to collaborate in reflecting and developing mechanical affective abilities, we should accept the emotion definitions, theories, and models from other disciplines, like computer science and (social) robotics, as specific emotion theories that are possibly able to explain emotions with their specific limits (all emotion theories have these limits, they are simply different for each and every theory). This means, we should include them as equal candidates for emotion theories that potentially explain emotions within living beings, too. This will help us to avoid problems such as those that occurred when psychologists found the emotion theories of their computer scientist collaborators too old-fashioned (Broekens 8). We should keep in mind here that if the aim is to model affective abilities in artificial systems, there are limited possibilities of translating the wordy theories into a relatively simple and at the same time more complex model and finally into numbers. If we, however, accept that there can be adequate emotion definitions that may not fully hold for a human being (as well as that emotion definitions made for humans may not hold for other kinds of systems or even children – as we have seen in the brief distinction between cognitivist and non-cognitivist emotion theories), we can claim for logical reasons that a 'genuine' emotion comes out of an artificial system if an emotion theory is translated and modelled into that system and if there is an outcome that results from the emotional program. With this view, we would at the same time avoid 'speciesism'. As already indicated, machinic emotions may be very different from emotions of other systems – but not only from those. As there are many different artificial systems and different emotion theories that are used to model their emotions, many different behaviors and mechanisms can be understood as emotions.

It's all about imagination

No matter which theory is used to model affective abilities in artificial systems, in many cases there will be human beings interacting with these systems. For instance, robots with emotional abilities are used for therapeutic settings with autistic children. Among others, Cabibihan et al. provide evidence that autistic children prefer to interact emotionally with robots and that this can help to facilitate the interaction with other humans, too.

One of the main goals of equipping artificial systems with affective abilities is to facilitate human-machine-interaction. This can be very useful in industrial settings where the worker is obliged to work with a robot that is very boring or that the worker does not understand very intuitively. In such cases, the amelioration of working conditions is possible. Another possibility of human-robot-interaction is found within a capitalist context. For instance, especially in Japan but sometimes also in Europe, and as already briefly described in one encounter above, the robot Pepper can be spotted in sales or customer service environments, for instance in shopping malls, airports, and karaoke bars.

The crucial point in all of these machinic varieties and human-machine-encounters is imagination. According to a study of Heider and Simmel, even the simplest shapes are already anthropo- or at least bio-morphized (Heider and Simmel 246). Humans ascribe intentions to the simplest moving forms even though they know that they do not have them. Moreover, humans attribute affectivity to simple shapes (de Rooij et al. 2). With a more complex design, the possible ways of bio- or anthropo-morphizing a thing increase in scope. The human expectations of this technology rise and the moment of deception becomes longer and more dense. The 'uncanny valley' graph shows various intensities of anthropomorphism (Mori 99). It is highly controversial for at least two reasons: 1) There is much empirical evidence for and against it that cannot be true at the same time (e. g. Misselhorn; Bartneck and Ishiguro); and 2) It implies a strong normative dimension that holds the 'healthy body' as the ultimate ideal. Nevertheless, the uncanny valley is used (almost?) always as a reference in (social) robotics research and the modelling of artificial agents, avatars, or movie characters.

Thus, as human beings have the tendency to anthropomorphize, they will likely compare the outcoming emotional reactions to human emotional reactions. Furthermore, depending on e.g. the personality or information and / or education about artificial systems, human beings may have a completely different understanding of affectivity in general, and of what artificial systems are capable of. Apart from the scientific discourse, the main sources of information about this topic are, besides one's own affectivity, media and science fiction stories that sometimes tend to converge with each other. Herbrechter suggests a new media genre resulting from the convergence of fiction and facts: "Science Faction" (Herbrechter 101). As a result, one urgent question is how to separate unrealistic ideas of machinic affective abilities from what is actually happening in science to finally break with the perceived mysteriousness of artificial systems due largely to human imagination (Sharkey and Sharkey 12, 18).

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Works cited

Bartneck, Christoph and Ishiguro, Hiroshi et al. "My Robotic Doppelgänger." *The 18th IEEE International Symposium on Robot and Human Interactive Communication Toyama*, Japan, 2009, pp. 269-276.

Bennett, Casey C. and Šabanović, Selma. "Deriving Minimal Features for Human-Like Facial Expressions in Robotic Faces.".*International Journal of Social Robotics*, 6 (3), 2014, pp. 367-381. DOI:10.1007/s12369-014-0237-z.

Boden, Margaret. *AI: Its Nature and Future.* Oxford University Press, 2016.

Broekens, Joost. "Modeling the Experience of Emotion." *International Journal of Synthetic Emotions*, vol. 1, no. 1, 2010, pp. 1-17. DOI:10.4018/jse.2010101601.

Cabibihan, John-John, et al. "Why Robots? A Survey on the Roles and Benefits of Social Robots in the Therapy of Children with Autism." *International Journal of Social Robotics*, vol. 5, no. 4, 2013, pp. 593-618. DOI:10.1007/s12369-013-0202-2.

Colombetti, Giovanna. *The feeling body. Affective science meets the enactive mind*. MIT Press, 2014.

Damiano, Luisa, et al. "Towards Human-Robot Affective Co-evolution Overcoming Oppositions in Constructing Emotions and Empathy." *International Journal of Social Robotics*, vol. 7, no. 1, 2015, pp. 7-18. DOI:10.1007/s12369-014-0258-7.

Damiano, Luisa and Dumouchel, Paul. "Anthropomorphism in Human–Robot Co-evolution." *Frontiers in Psychology,* vol. 9, 2018, DOI:10.3389/fpsyg.2018.00468,

Darwin, Charles. *The Expression of the Emotions in Man and Animals.* Dover Publications, Inc., 2018.

Dautenhahn, Kerstin, et al. "KASPAR - A Minimally Expressive Humanoid Robot for Human–Robot Interaction Research." *Applied Bionics and Biomechanics*, vol. 6, no. 3, 2009, pp. 369-397, DOI:10.1155/2009/708594.

Deonna, Julien A. and Teroni, Fabrice. *The Emotions: A Philosophical Introduction.* Routledge, 2012.

de Rooij, Alwin, et al. "Abstract Expressions of Affect." *International Journal of Synthetic Emotions,* vol. 4, no. 1, pp. 1-31, DOI:10.4018/jse.2013010101

Ekman, Paul and Friesen, Wallace V. "Measuring Facial Movement." *Environmental Psychology and Nonverbal Behavior*, vol. 56, no. 1, 1976, pp. 56-75.

Ekman, Paul. "Are There Basic Emotions?" *Psychological Review,* vol. 99, no. 3, 1992, pp. 550-553.

Ekman, Paul. "Basic Emotions." *Handbook of Cognition and Emotion*, edited by Dalgleish, Tim, and Power, Michael J., Wiley, 1999, pp. 45-60.

Fong, Terrence, Nourbakhsh, Illah, and Dautenhahn, Kerstin. "A Survey of Socially Interactive Robots." *Robotics and Autonomous Systems,* vol. 42, no. 3, 2003, pp. 143-166, DOI:10.1016/S0921-8890(02)00372-X.

Heider, Fritz, and Marianne Simmel. "An Experimental Study of Apparent Behavior." *The American Journal of Psychology*, vol. 57, no. 2, 1944, pp. 243-259, DOI:10.2307/1416950.

Herbrechter, Stefan. *Posthumanismus. Eine kritische Einführung*. Darmstadt: WBG, 2009.

James, William. “What is an Emotion?” *Mind*, vol. 9, no. 34, 1884, pp. 188-205.

Kühfuß, Fabian. *Nintendogs.* Video installation. Nintendo DS, microcontroller, stepper, aluminum frame, software, 2017.

Marsella, Stacy et al., “Computational Models of Emotion.” *A Blueprint for Affective Computing-A sourcebook and manual*, edited by Scherer, Klaus R. et al., 2010, pp. 21-46.

Minsky, Marvin. *The Emotion Machine: Commonsense Thinking, Artificial Intelligence, and the Future of the Human Mind.* Simon & Schuster, 2006.

Misselhorn, Catrin. “Empathy with Inanimate Objects and the Uncanny Valley.” *Minds and Machines*, vol. 19, 2009, pp. 345-59. DOI:10.1007/s11023-009-9158-2.

Mori, Masahiro. “The Uncanny Valley.” *IEEE Robotics & Automation Magazine*, vol. 19, 2012, pp. 98-100. DOI:10.1109/MRA.2012.2192811.

Nussbaum, Marta C. “Emotions as Judgments of Value and Importance”. *Thinking about feeling: Contemporary philosophers on emotions*, edited by Solomon, Robert C., Oxford University Press, 2004, pp. 183–199.

Picard, Rosalind. *Affective Computing*. MIT Press, 1997.

Rincon Ardila, Liz et al. “Adaptive Fuzzy and Predictive Controllers for Expressive Robot Arm Movement During Human and Environment Interaction.” *International Journal of Mechanical Engineering and Robotics Research*, vol. 8, no. 3, forthcoming 2019.

Russell, James A. and Mehrabian, Albert. “Evidence for a Three-Factor Theory of Emotions.” *Journal of Research in Personality*, vol. 11, no. 3, 1977 pp. 273-294. DOI:10.1016/0092-6566(77)90037-X.

Russell, James A. “Core Affect and the Psychological Construction of Emotion.” *Psychological Review*, vol. 110, no. 1, 2003, pp. 145-172., DOI:10.1037/0033-295x.110.1.145.

Sharkey, Noel and Sharkey, Amanda. “Artificial Intelligence and Natural Magic.” *Artificial Intelligence Review*, vol. 25, no. 1-2, 2007, pp. 9-19. DOI:10.1007/s10462-007-9048-z.

Singh, Angad. “’Emotional’ Robot Sells Out in a Minute.” *CNN Business*, 23 Jun. 2015, https://edition.cnn.com/2015/06/22/tech/pepper-robot-sold-out/index.html.

Stephan, Achim. “Zur Natur künstlicher Gefühle.” *Natur und Theorie der Emotion*, edited by Stephan, Achim, and Walter, Henrik, mentis, 2003, pp. 309-324.

Suchman, Lucy. *Human-Machine Reconfigurations.* Cambridge University Press, 2007.