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Paradoxes of Interactivity

Perspectives for Media Theory,
Human-Computer Interaction,
and Artistic Investigations

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Current findings from anthropology, genetics, prehistory, cognitive and neuroscience indicate that human nature is grounded in a co-evolution of tool use, symbolic communication, social interaction and cultural transmission.
Interactivity is a key for understanding the new relationships formed by humans with social robots as well as interactive environments and wearables underlying this process. Of special importance for understanding interactivity are human-computer and human-robot interaction, as well as media theory and New Media Art. »Paradoxes of Interactivity« brings together reflections on »interactivity« from different theoretical perspectives, the interplay of science and art, and recent technological developments for artistic applications, especially in the realm of sound.

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THE CO-EVOLUTION OF HUMANS AND MACHINES: A PARADOX OF INTERACTIVITY

Uwe Seifert

The Meaning of “Paradox”

What is meant by the expression “paradox” in “Paradoxes of Interactivity”? “Paradox” as used in the title of the book refers to the ordinary meaning of the word, and not to the well-known paradoxes of logic and mathematics such as Russell’s[1] set-theoretical paradox or Zeno’s[2] paradoxes of plurality and motion. The semantic field of the ordinary meaning of the word “paradox” derives from the ancient Greek word “parádoxos” consisting of “pará” meaning “contrary” and “dóxa” meaning “opinion”. In Book V of his “Republic” Plato[3] speaks of “paradoxos logos”. Used in this sense the meaning of “paradox” is “a statement contrary to expectation”, “an incredible statement”, “a statement contrary to accepted opinion”, “against common sense or ordinary opinion”, “provocative to accepted opinion or common sense”, “contrary to generally accepted belief” or “something surprising”. What are the provocative or incredible ideas associated with “interactivity”?

Interactivity: A Semantic Field

In general, an explanation of “interactivity” or “interaction” refers back to “action”, and in the social sciences action is presupposed to depend on an active human subject intentionally acting upon an object or another subject. Interaction only takes place between humans, because objects, like machines, are incapable of intentionality. In the case of human action humans are ascribed agency. In sociology “agency” is often contrasted with “structure”. But actually, structure is both an outcome of previous agency and a constraint upon it. Two semantic fields can be associated with “agency”. First, in the social sciences the sense of “agency” is mainly judicial, political or economical. This meaning is related to authority and assignment of power or official duties to humans, e.g. “assignee” or “agent”. The second meaning of “agency” and “agent” is mostly found in the natural sciences such as chemistry, biology, and physics. It is associated with effect, tool, activity, e.g. “protective agent”. To summarise: There are two fields of meanings concerning “agency”, “agent”, “action”, “interaction” and “to act upon”. One semantic field concerns the social sciences, and strongly relates to the idea of an intentional being, a human. The other concerns the natural sciences and refers to the idea of effect.

1 Russell 1903, § 101

2 Salmon 2001

3 Plato’s “Republic“ 472 a6; see Liddell/Scott 1996, p. 1309

With the advent of computational technology and systems the situation has changed: machines are attributed the active role in human's use of machines. They become subjects of actions and agents. One speaks of humans interacting with computers.

Agent technology and social robotics are two important recent examples to illustrate that the difference between humans and machines is becoming increasingly blurred. The meaning of "agent" applied in the social sciences only to human agents is being transferred to software: Special tasks such as internet searches and communication on behalf of a human are assigned to personal software agents.[4] In entertainment, therapy, e.g. autism therapy, and at home, e.g. as a robot companion, robots are interacting with humans. Furthermore, ubiquitous computing seems to make the computer "disappear" and at the same time be more and more entangled in day-to-day life: Things are beginning to talk.[5]

Furthermore, the asymmetric relation of human's use of machines is becoming symmetric. Machines are becoming the subject of interaction. Humans are interacting with machines, machines are interacting with machines and humans are interacting with humans via machines. In general, there are hybrid networks consisting of human and machine interacting with each other. The use of "interactivity" suggests that the difference between humans and machines evaporates. This is the main paradox associated with "interactivity"!

Humans and Machines: An Evolving Discontinuity

"Interactivity" indicates that at present a phase of fundamental change is being undergone in the ontological difference between humans and machines: This discontinuity is beginning to disappear. This important insight has been realised but articulated differently by many authors from different disciplines.[6] Especially Bruce Mazlish developed this insight further and pointed out that in order to cope with emerging social and cultural problems humans must accept the continuity of humans and machines. His thesis is that "man is breaking past the discontinuity between himself and machines."[7] Mazlish argues: Man is now becoming aware that "his own evolution is inextricably

4 Payr/Trappl 2004; Dautenhahn 2002

5 For instane, O'Sullivan/Igoe 2004 and Igoe 2007 introduce into physical computing in media art and design using Arduino, Processing and other "tools".

6 E.g. Robertson 1998, 2003; Ford/Glymour/Hayes 2006; Hubig/Koslowski 2008; Mazlish 1967, 1993

7 Mazlish 1967, p. 14; Mazlish 1993 elaborates the fourth discontinuity thesis.

interwoven with his use and development of tools"[8], and that "the same scientific concepts help explain the workings of himself and of his machines."[9]

At present the strongest scientific thesis in this sense is put forward by cognitive scientists: They argue that human beings are (logical) automata or that all natural human functions are best explained by (finite) automata in the sense of automata theory.[10]

Mazlish's claim is strongly supported by the emergence of new scientific disciplines, subdisciplines and research areas as well as art forms and cultural applications of computing, such as, to mention just a few, cognitive science, computational and cognitive neuroscience, techno- and biosciences, ubiquitous, physical and art computing, social and educational robotics, neuro-robotics, human-computer and human-robot interaction, interaction design, and interactive and new media art.

"Action" and "Interaction": Some Definitions

These developments require the social sciences, especially sociology, to interpret "interaction", "interactivity", "agency" and "agent" in the same manner as the natural sciences. Mario Bunge developed definitions of these terms whose meanings encompass both the social and the natural sciences.[11]

He considers "action" as a general (ontological) concept. The general idea captured in formalising the action relation is "What one thing does to another."[12] In his formalisation[13] Bunge uses concepts from set theory in order to define the action relation "x acts upon y" or "the action that thing x exerts on thing y". The expression "x acts upon y" is defined as a set-theoretic difference or relative complement of the history of y in the presence of x, and the history of y in the absence of x. The history of an object x is formed by the values v of its state function F for all time points t over a time period T. A state function F can be conceived of as a list of all known properties for some kind of objects. The concept of "interaction" is based on the definition of "to act upon": Two different things interact if and only if each acts upon the other. Human action appears as a special case of action. An action is a human action if and only if at least the agent of the action relation is a per-

8 Mazlish 1967, p. 14

9 Mazlish 1967, p. 14

10 E.g. Boden 2007; Burks 1972-73, 1990; Nelson 1988. Concerning the terms "machine" and "finite automata" see Minsky 1972, pp. 1-7 and pp. 11-31.

11 Bunge 1998, 2003

12 Bunge 2003, p. 9

13 Rudolf Kaehr's contribution takes a formalised approach to interaction. Kaehr's contribution should be viewed in the context of Gotthard Günther's ideas concerning the formalisation of the ideas of an "objective spirit/mind" and dialectic logic.

son. A social action is an action, in which both relata, agent and patient, are persons or one of them is a social system or public good. Agent and patient are defined as relata of the action relation. In an action relation "x acts upon y" the relatum x is called "the agent" and y "the patient", if x acts upon y. Both entities are said to "interact" in case the patient y reacts back on the agent x that initiated the process, i.e., y acts upon x, and y becomes the agent and x the patient. In such a case, except for practical purposes, the agent/patient distinction disappears. Based on these definitions, Bunge defines several other concepts associated with "action" such as "consequence of an action" and "reaction".

As exemplified by Mario Bunge's definition of terms such as "action" and "interaction", the meanings of "action" and "interaction" encompass human and non-human actions. Human actions and interactions form a special case of the broader definition of "action" and "interaction" and, in general, for the relata of interactions no distinction is made concerning agenthood and patienthood.

Interactivity and Interaction as Symmetrical Relations

Even if it is not necessary for action and agency to be associated with humans, as shown by the definitions given by Mario Bunge, it can be seen in sociology and philosophy of technology that these terms are often only ascribed to humans and not to machines. For example, in the German synthetic or pragmatic philosophy of technology developed by Hans Lenk and Jürgen Ropohl, humans interacting with machines in order to achieve a goal are considered to form an integral system, a socio-technological action unit.[14] In this view, even though a machine and a human form an integral action unit, the machine only concurs to the human action. A machine is not considered as an agent or actor, because it lacks intentionality and (human) purpose. This restriction implies that the action relation is thought to be asymmetric concerning the kinds of relata. Only a special kind of relata can be agents. Taking into account particularly recent directions of research into human-computer interaction (HCI) and human-robot interaction (HRI), concepts or theories that assign activity only to humans and passivity to machines seem dubious.

Bruno Latour's actor-network theory and socionics,[15] an approach to sociology which combines computer science and sociology, are in contrast

14 The German term is "*soziotechnisches System*".

15 Werner Rammert's contribution addresses some implications of socionics for interaction.

to Hans Lenk's and Jürgen Ropohl's synthetic and pragmatic philosophy of technology.[16] These theoretical approaches propose considering the action relation between humans and machines to be symmetrical, and advocate a kind of anthropology, especially a symmetrical anthropology, which views the roles of machines in human-machine interaction in general to be equated with human roles.

The insight into the viewing of human-machine systems as integrated systems has been made by Arthur W. Burks for computers in connection with the most effective use of both humans and computers. He uses the term "human-computer combines"[17] and points out the importance of the social implications of their use: "Electronic computers are the first active or "live" mathematical systems. … The most effective use of computer programs is to instruct computers in tasks for which they are superior to humans. Computers are being designed and programmed to cooperate with humans so that the calculation, storage, and judgment capabilities of the two are synthesized. The powers of such human-computer combines will increase at an exponential rate as computers become faster, more powerful, and easier to use, while at the same time becoming smaller and cheaper.[18] The social implications of this are very important."

So far, our discussion of human-machine interaction has revealed two important aspects of the human-machine relationship: 1) In general, there is no logical necessity to associate "action", "interaction", and "interactivity" only with humans, especially not in the case of human-computer and human-robot interaction. 2) Furthermore, human-machine systems form an integrated system that increases the power of both human and machines.

Concerning the goals of artificial intelligence, the idea of thinking machines and the discussions about human and machine intelligence, Harel makes the following distinction: "Perhaps, instead of AI, "artificial intelligence", the emphasis should be on IA, *intelligence augmentation*, which is the development of computerized tools that enhance human intelligence and improve its functioning. Combining the best aspects of human and machine may bring about that neither can do in its own."[19]

Burks describes this situation for scientific research on goal-directed and intentional systems for developing robots: "The ways in which models are used by goal-directed systems to solve problems and adapt to their environment are currently being modelled by human-computer combines. Since

16 See Maring 2008, p. 118.

17 Burks 1999, p. 167

18 This indicates the relevance of the human-in-the-loop.

19 Harel 2004, p. 400. Technologically speaking, at present most "interactive" systems for social or artistic interactions are *reactive* systems. See Harel 2004 for more information on reactive systems.

computer software can be converted into hardware, successful simulations of adaptive uses of models could be incorporated into the design of a robot. Human intentionality involves the use of model of oneself in relation to other and the environment. A problem-solving robot using such a model would constitute an important step toward a robot with full human powers."[20]

Science, especially cognitive science and research on human-computer and human-robot interaction, uses interactive art as a test bed in order to study action, perception, and cognition. This idea is elaborated in the next paragraph.

Interactivity and Cognition: Environments, Affordances, and Effectivities

It is important to note that the internal model of oneself is used in relation to others and not only to an environment. Furthermore, it must be pointed out that human interaction and communication takes place in a social and cultural environment rather than in a biological or physical environment. A social or cultural environment differs in many respects from a natural environment. The most important difference seems to be the use of symbolisation in social and cultural interaction and communication.

An agent's situatedness and "interactions" with an environment are highly important for the study of cognitive and perceptual capacities. In the context of these studies the concept of "affordances" is essential. The idea of "affordances" plays an important role both in the study of human-computer interaction[21] and interaction design and in neuro-robotics and cognitive and behavioural robotics. Gibson introduced the term "affordance" to the psychology of perception, and Norman to human-computer interaction and interaction design. For Gibson affordances are action possibilities available in an environment, independent of an agent's ability to perceive these possibilities. These are the actual possibilities of the environment. Affordances are conceived of as information in the sensory stream concerning opportuni-

20 Burks 1999, p. 168

21 The use of methods from human-computer interaction in non-technological context in combining HCI research and interactive art is a new emerging field, e.g. Höök/Sengers/Andersson 2003. At first glance there seems to be a difference between actions in everyday life, at work and art. It is possible to think of a work of art as consisting of interacting objects that humans are passively experiencing. In such a case humans are patients, and the artwork is the agent acting upon humans. Another more general scenario is that humans play an essential role in interactive art and are acting upon the objects and machines: This is the human-in-the-loop. In interactive art the human is necessary for interaction.

ties for action in and provided by the environment. Norman uses the term "affordances" for perceived possibilities, even if they may not actually exist.[22]

"Effectivities" is the concept complementary to "affordances". They "are the range of possible deployments of the organism's degrees of freedom," and "… the development of novel effectivities creates opportunities for the recognition of new affordances, and vice versa."[23]

In general, affordances provide cues to the operation of objects. They are the link between tools or objects and the knowledge of their use, i.e. the operational chains.

Effectivities expand the range of affordances. Gibson's and Norman's concepts of "affordances" neglect affordances in the case of social interaction, i.e. where the tools or objects are robots or humans. It might be a good idea to expand the ideas of "affordances" and "effectivities" to the study of social human-machine interaction, especially human-robot interaction and media art. To what extent are the actions of others in social interaction guided by affordances and effectivities? What the effectivities and affordances in social and emotional interactions with machines are remains an open question for research.

As noted previously, new media art and interaction art are increasingly being used as a test bed for scientific research. In interactive and media art human-computer combines can be used to enhance artistic productivity: artistic human-computer combines may form expression and structures that humans or computers alone can't achieve. At the same time, in applying theories and methods provided by the sciences, art explores the capacities of humans to sense, perceive, and act in unknown environments: Scientists become artists and artists become scientists. Therefore, in using human-computer combines and robots in science and art, it seems that the boundary between science and art is increasingly being blurred. One claim concerning this development is that art and science – as in the Renaissance[24] – are beginning to form a new alliance.[25] The artistic use of current developments in robotics,[26] artificial life,[27] software algorithms,[28] and agents[29] as well as

22 For a detailed analysis of different theoretical uses of "affordance" in Gibson 1979 and Norman 1988 see Gaver 1991 and McGrenere/Ho 2000.

23 Arbib 2006, p. 6

24 See Douglas Robertson's analysis for science and everyday life.

25 Hans Diebner's contribution elaborates this idea.

26 On the artistic use of robots see the contributions by Suguru Goto; Gil Weinberg.

27 See the contributions by Jin Hyun Kim; Christoph Lischka.

28 See the contributions by Frieder Nake; Julian Rohrhuber.

29 See the contribution by Georg Trogemann, Stefan Göllner, and Lasse Scherffig.

mixed, augmented and virtual reality[30] makes the relocation of the relationship between humans and artefacts evident.

New Media Art is seen in this context as a field in which art, science and technology are interwoven. As media artists are not only involved in artistic practices, but also in investigations analogous to science,[31] (artistic) creativity is needed in science to deal with new epistemological problems which come to focus through newer technologies.[32] Technologies are not only a means to achieve a goal, but rather a mediator for artistic and scientific experiments, which serves as component of efficiency respectively effectiveness.[33]

Interactivity and Media Theory

The transformation of technical tools, which began with the advent of digital technologies and led to the so-called New Media, changes our habitual modes of media use, reshapes our experience mediated by media, and opens up the possibilities of new designs of artistic and scientific experiments. Especially, a Media Theory concerning New Media, and particularly New Media Art, needs an alternative view to traditional conceptualisations of agency and interactivity, within a conceptual framework in which human-machine interaction can be based on an asymmetric relation and a co-active taking of effect during this interaction can be seriously investigated. In this context, rethinking “interactivity” opens a perspective for media theory from the point of view of cultural science and humanities which directs a research focus towards different themes related to New Media.

In Germany, there has been a paradigm shift within the humanities so that different conceptions of “Medien” (media) have come to the fore since the 1990s as a paradigm in contrast to “Geist” (spirit) and “Kultur” (culture). Contrary to media computing or psychology, media theory, oriented towards cultural science, surveys the operations of media which form and constitute the mediatised. Media act as preconditions for cultural semantics and psychological experiences. Research focuses were traditionally directed towards technical apparatuses or symbolic means, assuming some kind of “pure” meaning or intentional communication. Newer approaches of media theory do not assume that there is media-free and pre-medial meaning, information or intention that can be conveyed by media. Rather, media not only

30 See the contributions by Antonio Camurri, Barbara Mazzarino, and Gualtiero Volpe; Monika Fleischmann and Wolfgang Strauss; Ludwig Jäger and Jin Hyun Kim; Sybille Krämer; Martina Leeker.

31 See the contributions by Hans Diebner; Julian Rohrhuber.

32 See the contributions by Hans Diebner; Christoph Lischka.

33 See the contributions by Werner Rammert; Julian Rohrhuber.

act as an indifferent means of conveying the mediatised, but also participate in its shaping.[34] Therefore, "mediality" as the main operation of media which refers to the relation of a medium to the mediatised comes to the fore. The traditional concept of interactivity is not commensurable with the basic idea underlying this paradigm for media research within cultural science.

The main research interest of media theory related to interactive media is the question of how different media formats may have an effect on the meaning formation, information or experience generated co-actively by interactants.[35] For instance, how the practices of virtuality offer the possibility of interactivity with symbol structures, makes clear the difference of computer-based media from literal media.[36] Information technological and artistic experiments with HCI and HRI can therefore be investigated in respect of medial operations of newer technologies[37] which can not only serve as an analysis of mediality of New Media, but also have an impact on information technological research on HCI and HRI and artistic practices.

Interactivity and Emotion: Relational Artefacts

So far, interactivity and interaction have been dealt with in connection with the logical problem of defining "action" and "interaction" and discussions in the philosophy and sociology of technology concerning its relational property as being either symmetric or asymmetric. Furthermore, the importance of considering human-machine combines as integrated systems and, especially for human-computer interaction, as augmenting the power of both humans and computers for scientific research and artistic projects was mentioned. The convergence of art and science in using interactive art as a test bed for testing scientific hypotheses was noted. The importance of distinguishing between a natural and a social or cultural environment was pointed out. This distinction is based on symbolisation for communication, information exchange and transmission in cultural or social environments. Media theory was introduced as a point of view from the humanities concerned with the role of media in symbolisation and meaning formation. However, so far, the importance of emotional and social interaction between humans and machines has been neglected.

In the epilogue of the 2004 twentieth-anniversary edition of her famous "The Second Self: Computers and the Human Spirit" from 1984 the psychoanalyst Sherry Turkle reflects on the present situation concerning the rela-

34 Tholen 2005, p. 166

35 See Martina Leeker's contribution.

36 See Sybille Krämer's contribution.

37 See the contribution by Ludwig Jäger and Jin Hyun Kim.

tion between humans and machines. For her the main question is not about the real emotional and intellectual capacities of machines, but rather about human vulnerability and the human self-image. In analysing the present human-machine relationship and the current technological and social developments, she coined the term “relational artifacts” for artefacts that “ask their users to see them not as tools but as companions, as subjects in their own right”[38] that “… present themselves as sentient and feeling creatures, ready for relationship.”[39] For Sherry Turkle “The new questions are not about whether relational artifacts will really have intelligence and emotions but about what they evoke in their users.”[40] The question concerns “…, what *we* will be like”[41] and not what computers or robots can do. Furthermore, she points out that social and emotional interaction with machine is no longer science fiction, but rather social reality, and may affect the way humans think about themselves and their social relations: “The introduction of robotic helpers in nursing homes, …, is now being presented in the United States as potential social policy. […] How will interacting with relational artifacts affect people’s way of thinking about what, if anything, makes people special? The sight of children and the elderly exchanging tenderness with robotic pets brings science fiction into everyday life and technophilosophy down to earth. The question is not whether children will love their pet robots more than their real life pets or even their parents,[42] but rather, what will loving come to mean.”[43]

The last paragraphs show that, in interacting, human and computers form an integrated whole, and it seems appropriate to conceptualise the interaction of humans and computers as a symmetric relation. Computers are not only conceived of as tools; rather they are best conceptualised as “partners”, because computers and robots are increasingly, just like humans, acting in social and cultural environments. Symbolisation was identified as important in order to distinguish interaction with natural environments from interaction in social or cultural environments. As a final step the current developments in technology and interaction are put into a historical and evolutionary perspective of humankind.

38 Turkle 2005, p. 289

39 Turkle 2005, p. 288

40 Turkle 2005, p. 294; Fellous/Arbib 2005 contains further information of the current state of the art in research on the human brain, emotions, and robots. Social human-machine interaction based on detection and emulation of emotional states is treated e.g. in Picard 2002 and Breazeal 2002. Dautenhahn 2002, 2007 and Dautenhahn et al. 2002 treat social aspects of human-machine interaction in general.

41 Turkle 2005, p. 294

42 One may speculate that children will like their robot teachers more than their human teachers. For more information on learning, children, and robots, see Druin/Hendler 2000.

43 Turkle 2005, pp. 295

Human-Machine Interaction: A Broader View

A perspective which is not dealt with in this book but which underlies its conception is that tool use, symbolisation, and the evolution of the human mind are interwoven.[44] It is hypothesised that humankind is in a new phase of its cultural evolution which started with tool use and language 100 thousand years BP, continued with the invention of script 4000 years BC, and printing in 1500 AD and digital technology in the 20th century.

In Anthropology and prehistory the speciation of humankind has been associated with tool use, bipedality, increasing brain size and lateralisation, and symbolisation, to mention just a few of the proposed characteristics that distinguish humans from monkeys and apes. But now there is increasing evidence from primatology, anthropology and prehistory that social intelligence, interaction, and communication seem to be the causes of the differences that distinguish the hominin line from the other hominids. Since the advent of the human species, biological evolution has become more and more a cultural "evolution" in connection with symbolisation[45] and the tools for communication, information exchange and cultural transmission. The invention of writing systems and the printing press are well-known examples. But one has to bear in mind that these tools serve to facilitate social purposes such as cultural communication, information transmission and exchange.

The important point to note is that digital information technology operates in social realms of interaction, intelligence, and communication. Furthermore, it is important to note that it is not the material culture, i.e. the physical objects, in itself that is of importance, but rather the procedural knowledge associated with their use: the techniques or (procedural) knowledge of their use. The ethnologist Edwin Hutchins uses the term "cognitive artifact" as a concept which "… points not so much to a category of objects, as to a category of processes that produce cognitive effects by bringing functional skills into coordination with various kinds of structures."[46] Similarly in relation to tools and their use the French archaeologist Leroi-Gourhan pointed out the relevance of operational chains, i.e. operational sequences of technical actions.[47]

This may raise the question: What are the operational chains or cognitive artefacts which guide social interactions with machines, especially in

44 On human evolution, technology, and cognition see e.g. Audouze 1999; Gibson/Ingold 1993; Washburn 1960.

45 Donald 1991, 2001; Lock/Peters 1996

46 Hutchins 1999, p. 127. There seems to be a close connection to some uses of "media" and the idea of mediality in media theory. Unfortunately this relation cannot be elaborated here.

47 Leroi-Gourhan 1964; the French term is "chaînes opératoires".

an artistic context, and how do they change and develop in social human-computer and human-robot interaction? In general, how are they identified? All these questions are open for further research.

Conclusion

Currently we are at a crossroad in the co-evolution of humans and machines. We have identified symbolisation or symbolic communication and social interaction as the core of this co-evolution. It is claimed that the arts, especially New Media Art, in connection with physical computing, social robotics, and human-robot interaction, are becoming an extended "laboratory" for scientific research on social interaction and the human mind and its underlying psychological and neuronal mechanisms, as well as the cultural origins of higher cognitive functions. At the same time they are exploring new effectivities and affordances in the social or cultural art environments. Furthermore, interactivity in human-machine interaction is no longer merely a technological issue, or one only for scientists and engineers. Neither is interaction a topic only for psychologists and sociologists. The effects and consequences of human-computer and human-robot interaction are becoming an issue concerning all aspects of social human life and existence. Especially concerning the design of robots and human-robot interaction, ethical topics must be urgently addressed. Because of its impact on social communication and structure and the importance for the human self-image, new conceptualisations for describing, analysing, and theory-forming, as well as empirical research methods, are urgently needed to study this development. Media art in connection with cognitive and media science, human-computer and human-robot interaction is one of the best ways to cope with this need. It is not false to predict that in the near future the importance of its social, educational, political, philosophical, and theological implication will become tremendous. For example, Sherry Turkle observes: "Both psychoanalysis and computation challenge common sense understandings of action and responsibility because they get people thinking of a 'decentered' self – a self that is not a unitary, intentional agent."[48] The co-evolution of humans and machines will have essential effects on the human mind. Therefore, it is important to bear in mind Merlin Donald's assertion: "… the role of the individual mind is changing, not in trivial ways but in its essence. And these changes need watching."[49]

48 Turkle 2005, p. 356
49 Donald 1991, p. 360

This book gives a bird's-eye view on the current situation and some hints on what to look for in order to watch.[50]

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