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»A distinct element of play«. Scientific computer simulation as playful investigating

Abstracts

Drawing on concepts from the philosophy and sociology of play, this paper assesses the thesis that simulating in scientific computer simulation is playful investigating. Contrary to the seemingly clear discrimination of work and play, we argue that playful gaming is an essential element of work in scientific simulation. The features of play and playful gaming are concealed in the technology and methodology of computer simulation. Playful gaming strengthens the role of experience as an epistemic process in the research.

In Kritik einer simplen Trennung zwischen Arbeit und Spiel vertreten wir die These, dass die wissenschaftliche Tätigkeit des Simulierens spielerisches Forschen ist. Unter Bezugnahme auf Konzepte und Theorien aus der Philosophie und der Soziologie des Spiels wird das Spielen als wesentliches Merkmal des Arbeitens beim wissenschaftlichen Simulieren ausgearbeitet. Das Spielerische ist sowohl in der Technologie wie auch in der Methodologie der Computersimulation verankert – mit Konsequenzen für die Epistemologie der Computersimulation: Es stärkt Momente der Erkenntnis durch Erfahrung.

Introduction

There is no obvious plausibility to the claim that the activity of simulating fluid dynamics, tomorrow's weather, grasshopper bands, or intergovernmental negotiations on a computer is playful or involves playful steps on the side of the simulating scientist. On the contrary, Klabbers has emphasized the »distinction between playful gaming and serious simulation«.[1] He argues that the playfulness of humans and the ambiguity of play require an epistemology »very distinct from the rigor of performing simulation studies«.[2] However, his notion that the simulating scientist is a mere spectator observing the system's behavior is too simple. Relying on the extended mind hypothesis,[3] the philosophy of simulation argues that »running a computer simulation can be seen as a process in which a coupled system [of scientist and com-

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1 Jan H. G. Klabbers: »Terminological Ambiguity. Game and Simulation«, *Simulation and Gaming* 40 (2009), pp. 446–463, here p. 460.
2 Ibid.
3 See Andy Clark and David J. Chalmers: »The Extended Mind«, *Analysis* 58 (1998), pp. 7–19.

puter, N.J.S.]«[4] is operating. It is this concept of a coupled system of scientist and computer which motivates us to reconsider the simulating scientist. What is she doing? What is the act of simulating in scientific computer simulation? Isn't there an element of chance in any simulation run that is initiated by a simulating scientist? What do we learn about the act of simulating, if we apply Caillois's category of *alea* that includes chance-based play,[5] based in games of probability? Like Roulette, scientific computer simulation might fall into the *alea/ludus* section of Caillois's model. *Ludus* represents rule-based, regulated, formalized play. Although Caillois tends to assign an entire game or play activity to a single category of his taxonomy, most games have elements from several of his categories. Don't we also find elements of Caillois's categories of *mimicry* (English transl. »simulation« or »imitation«) and *agon* (»competition«) in the simulation model respectively simulation practice? Caillois's model may be useful for understanding the kinds of (play) experiences that the simulation model is and is not providing. More general, the concepts of play and game may help us understand the process of knowledge generation in scientific computer simulation.[6]

Our investigation centers on two questions: (1) What is the activity of simulating in scientific computer simulation? We will attempt to assess the thesis that simulat*ing* in scientific computer simulation is playful investigat*ing*, arguing there to be strong and modest versions of the claim. We will defend a modest sense of the thesis drawing on concepts from the sociology and philosophy of play as well (*playful gaming hypothesis*). (2) How do scientists obtain knowledge from running simulations? We claim that playful gaming in computer simulation strengthens the role of experience as an epistemic process in scientific research (*experience hypothesis*).

The argument of this article is developed in seven steps. Section 2 gives an account of the investigating activity. We present a preliminary definition of the investigative act of simulating in scientific computer simulations. In section 3, we distinguish three versions of the claim that simulating in scientific computer simulation is playful investigat*ing*. We defend the weak thesis by analyzing different aspects of play within scientific simulating (section 5) and point out that the idea that there is some element of play in simulation is not new (section 4). In section 6, we argue that playful gaming in computer simulation strengthens the role of experience as an epistemic process in scientific research. In section 7, we address the question how work,

4 Claus Beisbart: »How can Computer Simulations Produce New Knowledge?«, *European Journal for Philosophy of Science* 2 (2012), pp. 395–434, here p. 422.

5 See Roger Caillois: *Man, Play and Games*, New York: The Free Press of Glencoe 1961.

6 In the following, we will refer to several distinct definitions of play and game stated by philosophers and sociologists. If there is no reference to one of these authors we use the concept of game, if we want to emphasize the aspect of rules: the game is structured by self-imposed rules. We use the concept of play, if we want to emphasize the aspects of freedom, voluntariness and autotelicity. Both concepts are not used as synonyms.

play and technology are interrelated in scientific computer simulation. In the conclusion we offer reflections on the implications for the philosophy and epistemology of computer simulation and on playful investigating in general.

The Simulating Scientist and the Activity of Investigating

Scientific work in general can be seen as a quest beyond ordinary life by asking questions that are not about how to cope with life but how to describe, understand and explain the world in its theoretical, exemplary and abstract dimensions.[7] Scientific work as a practice has been researched, for example, in the Laboratory Studies. Dominique Vinck identifies their initial point in George Thill's work *La Fete scientifique* and summarizes his findings in a definition of scientific practice as »an action which invents intrinsic utopia with rational course«.[8] This view can be supplemented with Max Weber's perspective, who suggests a triangle, wherein beside the (a) rational, systematic and reviewable courses of target orientated scientific practices (b), the interests of the scientists shaped by curiosity and passion as well as (c) a touch of genius are constitutive elements.[9] This uncertain phenomenon of a spontaneous intuition is a main point in Charles Peirce's concept of abduction, where he argues that next to induction and deduction, the searching for rules is an important part of scientific work. This process can't be fully controlled, we can only produce settings in which spontaneous intuition flashes – typically in situations of very high or very low pressure.[10] To emphasize, the flashing intuitions and ideas are not products from outside the subject, but are results of a previous knowledge connected to the research aim and the specific situation.

The development of a scientific computer simulation model is a complex investigative activity.[11] From a technical point of view, the process of making a computer simulation study can be decomposed into several steps, including e.g. developing the

7 Klaus Holzkamp: *Wissenschaft als Handlung. Versuch einer neuen Grundlegung der Wissenschaftslehre*, Berlin: de Gruyter 1968, pp. 23–24.
8 Dominique Vinck: *The Sociology of Scientific Work. The Fundamental Relationship between Science and Society*, Cheltenham: Elgar 2010, p. 194. See George Thill: *La Fete Scientifique. D'une Praxeologie Scientifique a une Analyse de la Decision Chretienne*, Paris: Aubier Montaigne, Cerf, Delachaux & Niestle and Desclee De Brouwer 1973.
9 See Max Weber: *Politics as a Vocation*, Philadelphia: Fortress 1965.
10 See Charles S. Peirce: »Guessing«, *Hound & Horn* 2 (1929), pp. 267–282; Charles S. Peirce: »A Neglected Argument for the Reality of God. § 1 Musement«, in: Charles Harthorne and Paul Weiss, eds., *Collected Papers of Charles Sanders Peirce*, Cambridge: Harvard UP 1931, pp. 452–466 and Jo Reichertz: *Die Abduktion in der qualitativen Sozialforschung. Über die Entdeckung des Neuen*, Wiesbaden: Springer, 2013, pp. 117–118 and 120.
11 In all sections, we refer to Hartmann's definition of a simulation model: »a simulation results when the equations of the underlying dynamic model are solved. This model is designed to imitate the time-evolution of a real system. To put it in another way, a simulation imitates one process by another process« (Stephan Hartmann: »The World as a Process. Simulation in the

(mathematical) model, programming, parameterizing, calibrating, optimizing, testing and validating. A comprehensive list cannot be given, as some of these steps depend on the simulation study's objective. As Sundberg notes,[12] the discourse of simulation modelling sometimes conflates what the researchers are actually doing. Simulation modelling practice includes working with a dynamic model. This is considered to be theoretical and conceptual work, as well as technical work such as coding or debugging the computer program: »In fact, it involves a lot of hands-on work, especially in relation to implementation in existing computer programs«.[13]

While numerical modelling may be a collective enterprise (e.g. in astrophysics),[14] the simulationist's everyday work involves sitting alone, looking at a computer. Therefore, in particular, we want to focus on the practice of simulating scientists and reflect their activities as investigating subjects. According to Franz Breuer, ways of observing, measuring, experimenting, speaking and analyzing create a tie between the scientist as a subject and his phenomenon as an object. In the situation of simulating, the ›interaction‹ between the scientist and the simulation model is characterized by two elements: the computer as the scientist's instrument and the graphical user interface as the model's visualization of the results. Both co-define the ways of knowledge acquisition.[15] Certainly, it is possible to focus on the role of the calculating machine as an actor too, like the actor-network theory would suggest.[16] However, although we recognize the importance of computers in simulations, our concept of technology is more instrumental. In our view, technology is an extension of body and mind. Therefore we adopt De Preester's differentiation into extensions of *motor* capacities, *sensory* capacities and *cognitive* capacities.[17] Rather than an actor

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Natural and Social Sciences«, in: Rainer Hegselmann, Ulrich Muller and Klaus G. Troitzsch, eds., *Modelling and Simulation in the Social Sciences From the Philosophy of Science Point of View,* Dordrecht: Kluwer 1996, pp. 77–100, here p. 83; emphasis S.H.). This definition excludes simulations of static objects, e.g. Monte Carlo simulations. Both of our hypotheses are set up for the former type of simulations. Their relevance for Monte Carlo simulations should be investigated in a separate study.

12 See Mikaela Sundberg: »The Everyday World of Simulation Modelling. The Development of Parameterizations in Meteorology«, *Science, Technology, and Human Values* 34 (2009), pp. 162–181, here p. 178.

13 Ibid.

14 Mikaela Sundberg: »Creating Convincing Simulations in Astrophysics«, *Science, Technology, and Human Values* 37 (2012), pp. 64–87.

15 Franz Breuer: *Wissenschaftstheorie für Psychologen. Eine Einführung*, Münster: Aschendorff 1991, p. 77.

16 In this theory a principal and structural symmetry in the relationship of human actors and non-human actors like technologies as actants is claimed by Bruno Latour (Bruno Latour: *The Pasteurization of France*, Cambridge, London: Harvard UP 1988 and Bruno Latour: »On Actor-Network Theory. A Few Clarifications«, *Soziale Welt* 47 (1996), pp. 369–381) and Michel Callon (Michael Callon: »Some Elements of Sociology of Translation. Domestication of the Scallops and the Fishermen of St. Brieuc Bay«, in: John Law, ed., *Power, Action and Belief. A New Sociology of Knowledge?*, London: Routledge 1986, pp. 196–234).

17 Helena De Preester: »Technology and the Body. The (Im)Possibilities of Reembodiment«, *Foundations of Science* 16 (2011), pp. 119–137.

with agency, the computer is in the sense of the last dimension an extension of cognition, a position also well known as »The Extendend Mind«.[18] To consider the intense relation between human and technology, this position is complemented by Christoph Hubig's concept of the hybridization of human.[19] He asserts that in mixed realities an amalgamation of humans and technologies is more prevalent than an interaction between two independent entities.[20]

From an ethnographic point of view, scientific simulating may be defined as an interplay of activity and passivity, where on the one hand, theory and data are translated into program codes, and on the other hand, simulations run autonomously. The scientist is initiating simulation runs and waiting for the results, reassembling the model by changing some assumptions, initiating further simulation runs, waiting and so on. Here, the following two moments are of epistemic relevance: (a) the results becoming visible and (b) the decision making on how to proceed. Because of the invisibility of the calculations the computer makes, an element of surprise is symptomatic at the first moment. Doubtlessly, the scientist exactly knows the model assumptions she has implemented. However, a look at the simulation results is often a moment of unexpected findings. The second significant moment is the decision regarding which simulation to run next, characterized by scientific rationality, as well as creativity that arises from asking "what if?" – questions (this question is also highlighted by Turkle for simulations and Schön for experiments).[21] The way of scientific activity in this form is linear in the sense of a planned, structured and transparent research process with a clear target, but helical like a hermeneutical circle where the knowledge is generated stepwise by iterative improvements.

Three versions of the thesis

There are clearly a strong, a weak and a too weak version of the thesis that simulating is playful investigating. According to historian Johan Huizinga, sociologist Roger Caillois and philosopher Eugen Fink we define playful gaming in narrower sense as (a) free, voluntary and autotelic activity, (b) structured by self-imposed

18 Clark and Chalmers: »The Extended Mind«.

19 See Christoph Hubig: »Der technisch aufgerüstete Mensch. Auswirkungen auf unser Menschenbild«, in: Alexander Roßnagel, Tom Sommerlatte and Udo Winand, eds., *Digitale Visionen. Zur Gestaltung allgegenwärtiger Informationstechnologien,* Berlin, Heidelberg, New York: Springer 2008, pp. 165–176.

20 As a consequence, he points to the importance of transparency of technologies, traceable through a system of parallel communication where, despite of for granted taken interdependences, technologies and their effects are still in sight.

21 See Sherry Turkle: *Life on the Screen. Identity in the Age of the Internet*, New York: Simon and Schuster 1995, p. 52 and Donald A. Schön: *The Reflective Practitioner. How Professionals Think in Action*, London: Temple Smith 1983, p. 145.

rules, (c) effective for a fixed period and in a limited space, (d) consisting of actions totally focused on the situation and separated from everyday life.[22]

A strong thesis might claim that simulating is playful gaming in that it necessarily fulfils all these criteria. This thesis is obviously too strong. Phrasing the *strong simulating as playful gaming thesis* in terms of a necessary and sufficient conditions gives us an obvious method to refute it: Scientific simulating is not a fully free, voluntary and autotelic activity. It is not simply playful gaming. It is included in a research process at some scientific institution that aims at increasing our knowledge on nature or society. Thus, the strong thesis – that simulating essentially is playful gaming – is immediately prone to refutation; indeed, nobody has been bold enough to assert such a thesis. In fact, it is simply not necessary to hold the strong thesis in order to argue that the activity of simulating is often playful, or is even usually so.

The modest thesis allows us to retain the initial idea of simulating being playful gaming, noted in the opening of this essay, but to avoid the obvious limitations of the strong thesis. The *weak form of the simulating as playful gaming thesis* allows to set simulating as play if the primary defining criteria *a* to *d* are fulfilled to a great extent, or if some particular moments of simulating fulfil several of these criteria.

We distinguish the weak thesis from a thesis that is too weak. The latter thesis might claim that the simulating scientist is in a playful state of mind. This *simulating as being playful thesis* is too weak because many complex activities can be done with a playful attitude. As Salen and Zimmerman note, play is latent in any human activity.[23] We do not claim that simulating is a frolic scientific activity.

Before we defend the weak thesis, we point out that the idea of an element of play in simulations is not new.

»A distinct element of play«

In his definition of interactive simulation, Klabbers comes quite close to the thesis of this article:

> »Interactive simulation – that is, interconnecting simulation models and actors in one comprehensive framework – in principle serves the goals of the actors playing with the simulation model. While playing with simulation models, these actors construct knowledge that fits into and so changes their schemas«.[24]

22 See Johan Huizinga: *Homo Ludens. A Study of the Play-Element in Culture*, London, Boston, Henley: Routledge & Keagan Paul 1980, pp. 7–13; Caillois: *Man, Play and Games*, pp. 3–10 and Eugen Fink: *Play as Symbol of the World and Other Writings*, transl. by Ian Alexander Moore and Christopher Turner, Bloomington: Indiana UP, pp. 14–32.

23 See Katie Salen and Eric Zimmerman: *Rules of Play. Game Design Fundamentals*, Cambridge, Mass.: MIT Press 2004, p. 307.

24 Klabbers: »Terminological Ambiguity«, p. 456.

There is the idea that actors play with the simulation model. However, his notion of the simulating scientist is still that she is a spectator observing the simulation model's behavior.[25] The philosophy of science, though, argues that, strictly speaking, theories and most models cannot be observed.[26] Instead, the philosophy and sociology of science have described the simulating scientist's activity as modelling,[27] or storytelling.[28]

In her empirical investigations on simulation practices in meteorology and astrophysics, Sundberg finds that there are playful ways of learning how to handle simulation codes, e.g. when prearranged simulations serve as teaching tools. Senior astrophysicists spoke openly and spontaneously about playing: »if you would go over in the corridor where most of my students sit and you would follow their work for a day you would sort of see that there is a distinct element of play«.[29] Sundberg argues that the play with ›strange‹ results is a part of the socialization process into numerical simulation methods (similarly Dowling).[30] According to Sundberg, these findings echo on Turkles diagnosis of a postmodernist culture of simulation. Turkle considers simulation as the representation of reality in the postmodern era and simulating as the production or application of scientific models as well as computer games. In her analysis, she draws a line to the linear, logic and planned culture of calculation. In contrast, the culture of simulation is characterized by taking the computers virtuality for real and experiment with possibilities. In the postmodern society, this leads to a play with different and no longer distinguishable realities. In the context of scientific work, she reminds us on Levi-Strauss's term *bricolage* he uses for a kind of tinkering in scientific work by trying different ways of solutions and adapting models stepwise.[31] Although her view on simulating is characterized by the programming language of the late 1980 s and early 1990 s and that she is mainly inter-

25 See Ibid, p. 459.

26 See Wendy S. Parker: »Does Matter Really Matter? Computer Simulations, Experiments, and Materiality«, *Synthese* 169 (2009), pp. 483–496, here p. 489.

27 See Mikaela Sundberg: »Credulous Modellers and Suspicious Experimentalists? Comparison of Model Output and Data in Meteorological Simulation Modelling«, *Science Studies* 19 (2006), pp. 52–68.

28 See Gabriele Gramelsberger: »Story Telling with Code. Archaeology of Climate Modelling«, *TeamEthno-online* 2 (2006), pp. 77–84; Erica Mansnerus: »Modeling in the Social Sciences. Interdisciplinary Comparison«, *Perspectives on Science* 21 (2013), pp. 267–272 and Erika Mansnerus: »Using Model-based Evidence in the Governance of Pandemics«, *Sociology of Health and Illness* 35 (2013), pp. 280–291.

29 Mikaela Sundberg: »Cultures of Simulations vs. Cultures of Calculations? The Development of Simulation Practices in Meteorology and Astrophysics«, *Studies in History and Philosophy of Modern Physics* 41 (2010), pp. 273–281, here p. 278; Interview 2, quoted from Sundberg.

30 See Deborah Dowling: »Experimenting on Theories«, *Science in Context* 12 (1999), pp. 261–273, here p. 271.

31 See Turkle: *Life on the Screen*, p. 51.

ested in the changes of identity in the present age, she gives us an important indication of simulating as a form of play with scenarios and tinker with outcomes.[32]

Altogether, the idea of an element of play in simulations is not new. Unfortunately, we lack a precise hypothesis and a thorough analysis.

Scientific simulating as playful gaming

By considering the forms and dimensions of play, the freedom of play and the separateness of scientific computer simulations, we analyze and exemplify aspects of play in several steps of simulating.

The *alea/ludus* dimension of scientific simulating

In this subsection, we refer to Caillois's typology of games based on the categories competition *(agon),* chance *(alea),* simulation *(mimicry),* the capability of producing vertigo *(ilinx)* and a second dimension – *paidia/ludus* – that distinguishes fantasy from effort, patience, skill, or ingenuity.[33]

The *mimicry* dimension of Caillois's classification of games he translated as ›pretense‹ or ›simulation‹ refers to role-playing, or playing pretend. Even though there is an element of *mimicry* in the simulation model that may be perceived as pretending to imitate the target, this dimension of Caillois's classification will not serve as our main argument. We consider this to be a question for model theory,[34] rather than the philosophy of simulation.

We claim that significant steps in scientific computer simulation fall into the *alea/ludus* section of Caillois's model. His category of *alea* includes chance-based play, based in games of probability. Ludus represents rule-based, regulated, formalized play.

Every simulating scientist is concerned with exploring output through replications.[35] E.g., in the early steps of developing a simulation model the output often exhibits features that cannot be observed empirically, such as implausible or extreme values, spikes or no sensitivity to some changes in the model assumptions. They are

32 Ibid., p. 52.

33 See Caillois: *Man, Play and Games*.

34 See Daniela M. Bailer-Jones: »When Scientific Models Represent«, *International Studies in the Philosophy of Science* 17 (2003), pp. 59–74; Ronald N. Giere: »How Models are Used to Represent«, *Philosophy of Science* 71 (2004), pp. 742–752 and Roman Frigg: »Fiction and Scientific Representation«, in: Roman Frigg and Matthew Hunter, eds., *Beyond Mimesis and Convention,* Berlin: Springer, pp. 97–138.

35 See Sundberg: »Creating Convincing Simulations in Astrophysics«.

at first interpreted as clear signs of error. At that stage, simulationists are preoccupied with debugging and finding errors in codes. Each implausible output requires the scientist´s close look at the model code and a development of an ad hoc hypothesis on the reason behind this. Due to the epistemic opacity of the simulation results, the scientist cannot know in advance whether her ad hoc hypothesis will remove the implausible output or not.[36] Typically, such an ad hoc hypothesis will be modified in consecutive simulation runs after the new output has been examined. That, in turn, might have displayed a slightly different implausible output and perhaps even a new implausible output at another variable. Simulation output ›behaves‹ ›tricky‹ as a result of the often nonlinear and stochastic structure of the underlying mathematical model. At that point, the dimension of play is included. Some simulating scientists will enjoy the improvisational and innovative moments of developing new ad hoc hypotheses. The (more or less) immediate result from the next simulation run combines with the epistemic opacity and generates some kind of a chance-based game. However, it is even more than chance-based. The scientist will be ambitious. She knows that the results do not merely depend on chance. They depend on more or less understandable algorithms. *The results depend on your theory. If you understand them correctly you will develop a hypothesis and make a prediction of the new results that turn out to be correct in the next simulation run*. This is a wonderful, intellectually challenging game – not just a game of trial and error. By the way, the computer can be experienced as an opponent. The computer is responding quickly. The computer is a relentless opponent. The computer makes no mistakes. *The computer just proceeds in a binary way. Current, no current. Current, no current. You see immediately that your hypothesis was wrong.* However, the computer can also be deemed an ally. There is an element that falls into the *agon* section of Caillois's model.[37] The computer is an ally in your competition against yourself for the next fruitful hypothesis. The computer helps to identify the next fruitful hypothesis. The computer proceeds where the scientist can no longer control her deductions. Together, they defeat the limits of her reasoning. *Come on. Help me. Isn´t this true?* The sequence of human activities and computer processes is: Output interpretation, ad hoc hypothesis formulation, implementation on the computer, simulation run, visualization of new output (*ihero*). *Ihero, ihero, ihero, ihero*. Hundred-fold. Each output interpretation becomes an act of verification of your previous hypothesis. *Hero-v, hero-v, hero-v*. *Les yeux sont faits! Run! Wait. See. Failure – What a disappointment! Les yeux sont faits! Run! Wait. See. Failure – What a disappointment! ... Les yeux sont faits! Run! Wait. See. It has m o v e d! What a delight! It works!* All simulating scientists experience the tension. Successful scientists experience the delight. *This is*

36 Paul Humphreys: *Extending Ourselves. Computational Science, Empiricism, and Scientific Method,* Oxford: Oxford UP 2004.
37 See Caillois: *Man, Play and Games*.

a nice model! They experience setting the rules for a closed system. *What a wonderful small world!* In gaming simulation, the person who sets the rules for the interactions in the game is called GOD, meaning Game Overall Director. Imagine! *I am a GOD. This is my world. This is* my *world. This is* my *rain and this is* my *super nova exploding. Sarah and Jack, do you see* my *super nova exploding?* After many model super novae have exploded in a plausible way, less playful steps of model development follow. E.g., calibration and optimization can be done in a rather autonomous way by computer algorithms. Throughout the test of the simulation model, exploring output through replications becomes a more playful activity, again. As Sundberg notes for astrophysics, there are »many occasions on which it is uncertain whether one's output is wrong or reasonable«.[38] Surprising output receives much attention because it must be explained. The search for an explanation generates new sequences of the type *hero-v*.

It is the technology of the computer that allows the playful *ihero* and *hero-v* cycles. There is an element of repetition also typical in games.[39] After a basic model has been implemented, new simulation runs with slight modifications of the assumptions can be initiated in a convenient way and executed quickly. Even complex results can be visualized swiftly and in a way that supports understanding.

Each cycle is accompanied by emotions because each result of a simulation run is perceived as an event. Appraisal theories of emotions claim that emotions evaluate an event, the commissions and omissions of a person, or persons/objects.[40] Again, it is the technology of the computer generating results that are perceived as an event and thus creates hundreds and thousands of opportunities for the experience of emotions. Typically, the experience of disappointment prevails, sometimes mixed up with anger.

But in successful simulation studies, the delight of an intensity that can only be compared to the pleasure experienced in successful experiments is also experienced again and again.[41]

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38 Sundberg: »Creating Convincing Simulations in Astrophysics«, p. 71.

39 Hans Scheuerl: »Zur Phänomenologie des Spiels«, in: Ausschuß deutscher Leibeserzieher, ed., *Das Spiel*, Frankfurt on the Main: Limpert, pp. 29–43.

40 See e.g. Andrew Ortony, Gerald L. Clore and Allan Collins: *The Cognitive Structure of Emotions*, Cambridge: Cambridge UP 1988.

41 This subsection includes in paragraph three a piece of autoethnography (Carolyn S. Ellis: »Autoethnography«, in: Lisa M. Given, ed., *The Sage Encyclopedia of Qualitative Research Methods*, Vol. 1, London: Sage, pp. 48–51 and Carolyn Ellis, Tony E. Adams and Arthur P. Bochner: »Autoethnography. An Overview«, *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research* 12/1 (2011), Art. 10, 18 p.) and technography, and transcribes internal conversations (as theorized by Margaret S. Archer: *Structure, Agency, and the Internal Conversation*, Cambridge: Cambridge UP 2003) of one of the authors (NJS) from more than two decades of simulating practice. The internal conversations have been alienated by transferring them to another academic discipline. Autoethnography is an »approach to research and writing that seeks to describe and systematically analyze (graphy) personal experience (auto) in order to understand cultural experience (ethno)« (Ellis et al.: »Autoethnography«, p. 1). As Ellis,

We claim that there is a distinct element of freedom in scientific computer simulation. Admittedly, there are the laws of nature (in the sciences) or there are formal models based on social theory. Both set limits to the freedom of the scientist. However, these laws and models must be adapted and modified to make them run on a computer. These adaptations go far beyond discretization and dynamization. Morrison has put forward the hypothesis that there is a partial independence of scientific models vis-a-vis both theories and the world that makes them autonomous agents in the production of scientific knowledge.[42] Together with Morgan, she argues that simulation and modelling are closely associated.[43] She asserts that there is a »hierarchy of modelling« that is characteristic of computer simulation experiments. This hierarchy »begins with a mathematical model of the physical target system that is then discretized to produce the simulation model«.[44] The transition to a simulation model is characterized by several ruptures.[45] The simulation model includes elements not justified by the theory or by the model of the phenomenon, e.g. parameters without a theoretical interpretation,[46] algorithms compensating systemic errors or a lack of knowledge.[47] Lenhard uses the concept of plasticity to refer to the adaptability of

Adams and Bochner note, the type of writing accords to storytelling rather than to proposing or presenting a theory for which reason autoethnographic texts are »closer to literature than to physics« (ibid., p. 2). The reader of the text is not the »passive receiver of knowledge« but a co-participant who is involved in the story (see Ellis: »Autoethnography«, p. 50). Essential for the story are »private details of emotional and bodily experience« (Ibid.; Ellis et al.: »Autoethnography«, p. 4). In autoethnography, the criterion of reliability is a question of ›factual evidence‹ – is it still a true story or does the ›literary licence‹ lead to fiction? (see ibid., p. 10). Validity can be addressed by asking questions, such as: Can the reader see the world through the researcher's eye and deal with it? (see ibid.).

42 See Margaret Morrison: »Models as Autonomous Agents«, in: Mary S. Morgan and Margaret Morrison, eds., *Models as Mediators,* Cambridge: Cambridge UP 1999, pp. 38–65.

43 See Margaret Morrison and Mary S. Morgan: »Models as Mediating Instruments«, in: Mary S. Morgan and Margaret Morrison, eds., *Models as Mediators,* Cambridge: Cambridge UP 1999, pp. 10–37, here pp. 28–36.

44 Margaret Morrison: »Models, Measurement, and Computer Simulation. The Changing Face of Experimentation«, *Philosophical Studies* 143 (2009), pp. 33–57, here p. 55.

45 See Andreas Kaminski, Björn Schembera, Michael Resch and Uwe Kuster: »Simulation als List,« in: Gerhard Gamm, Petra Gehring, Christoph Hubig, Andreas Kaminski and Alfred Nordmann, eds., *Technik, List und Tod. Jahrbuch Technikphilosophie,* Zürich: Diaphanes 2016, pp. 93–121.

46 See Johannes Lenhard and Hans Hasse: »Fluch und Segen. Die Rolle anpassbarer Parameter in Simulationsmodellen,« in: Alexander Friedrich, Petra Gehring, Christoph Hubig, Andreas Kaminski and Alfred Nordmann, eds., *Technisches Nichtwissen. Jahrbuch Technikphilosophie 3*, Baden- Baden: Nomos 2017, pp. 69–84.

47 See Eric Winsberg: *Science in the Age of Computer Simulation*, Chicago: UP 2010, pp. 9, 16 and 46 and Johannes Lenhard: *Mit allem rechnen. Zur Philosophie der Computersimulation*, Bern: de Gruyter 2015, pp. 34–37.

simulation models.[48] The simulating scientist enjoys a significant freedom in specifying and adapting some elements of the simulation model.

There is even more freedom on another level: While the notion of target suggests that there is a fixed entity that has to be modelled, the boundary between what is included in, and what is excluded from the model, is often rather vague. This holds particularly for simulation models in the social sciences, where social, political and economic phenomena are highly interdependent. In addition, the degree of resolution of modelling the target (grain size or scale) may require not yet theorized model assumptions. Thus, during the development of a computer simulation model, many decisions must be made going beyond a mere implementation and representation of the preceding formal model.

Still on another level, the simulating scientist may even free herself from diverse, e.g. realist assumptions and create computer simulation models rather resembling to what Cooper has called possible worlds.[49] Like a thought experimenter, a simulating scientist may construct models of possible worlds. She may model and explore even counterfactual worlds. This leads to the concept of a playful space of possibility (›spielerischer Moglichkeitsraum‹) – a term used by Nordmann to characterize techno scientific research.[50] He argues that in the age of the techno sciences, research looks at the showily-dramatic (›theatralisch-dramatisch‹) aspect of the experiment. The experiment is reckoned primarily as an artificially induced presentation of a behavior that is intended to surprise us and discover the new. In this way, scientific computer simulation leaves history and the teleology of the political behind and enters possibly the realm of art. Hubig argues that technology not only refreshes predetermined possibility spaces, but creates new spaces of possibility.[51] It depends on the perspective of the observer whether these possibilities strike as real, de dicto, epistemically problematic, epistemically postulated, reflexive or performative.[52]

Notably, it is the technology of the computer requiring – in relation to the foregoing mathematical model – additional steps to provide elements of freedom to the simulating scientists. Also, it is the technology offering the freedom to play with a high number of possible worlds – owed to the rapidity of the computer processes.

48 See Lenhard: *Mit allem rechnen*, chapter 3.

49 See Rachel Cooper: »Thought Experiments«, *Metaphilosophy* 36 (2005), pp. 328–347, here p. 336.

50 See Alfred Nordmann: »Experiment Zukunft. Die Künste im Zeitalter der Technowissenschaften«, *subTexte 03: Künstlerische Forschung. Positionen und Perspektiven,* Zürich: Hochschule der Künste 2009, pp. 8–22, here p. 21.

51 See Christoph Hubig: *Die Kunst des Möglichen I. Grundlinien einer dialektischen Philosophie der Technik*, Bielefeld: Transcript 2006, p. 23.

52 See ibid., p. 169.

In contrast to the ordinary life with all its opaque interdependences and more vague than explicit social rules developed over a long period of time, in simulations just as in play, a small world in itself is created through a closed system of distinct rules in defined dimensions. The separateness of this small world can be experienced by the simulating scientist whenever she begins to work with the simulation model. She will experience what has been called a self-contained reality. William James and later Alfred Schütz both describe the variety of self-contained realities.[53] As non-paramount realities »the world of dreams, of imageries and phantasms, especially the world of art, the world of religious experience, the world of scientific contemplation, the play world of the child, and the world of the insane« are quoted by Schütz.[54] Every change between the everyday life and one of these realities is experienced as a shock,[55] a term which refers to Soren Kierkegaard's *leap* (orig. *Sprung*) used by Kierkegaard to describe essential decisions in religious attitudes.[56]

In addition, the aspect of separateness can also be observed on the level of effects of the simulation results. A simulated atomic explosion, a simulated climate catastrophe, and a simulated intergovernmental negotiation will not destroy physical goods, generate a climate catastrophe in the real world or solve a political problem. In this respect, simulations are separate from our daily lives. However, among the atomic powers of the world, the most advanced ones maintain the balance of terror by simulating atomic explosions. The results of simulated climate change influence politicians and their decision making. Basic research, like the simulation of intergovernmental negotiations do not change the world, it may, however, change our understanding of the negotiations, and have an influence on the level of discourses – be they scientific or public. In contrast, some results of simulations in the engineering sciences are getting implemented immediately into constructions. Thus, we assert that simulations are separated from everyday life in principal, but in opposition to play in games, their effects have the potential to influence the real world or are explicitly applied to do so.

Altogether, we argue that simulating in scientific computer simulation is playful investigating. Nevertheless, please note that on closer inspection, our weak thesis of scientific simulating as playful gaming addresses two analytically distinct levels.

53 See William James: »The Perception of Reality«, in: William James: *The Principles of Psychology*, Volume II, New York: Holt 1890, pp. 283–322 and Alfred Schütz: »On Multiple Realities«, in: Maurice Natanson, ed., *Collected papers. Vol. I. The Problem of Social Reality,* The Hague: Nijhoff 1962, pp. 207–259.

54 See Schütz: »On Multiple Realities«, p. 232.

55 See ibid., 231.

56 See Soren Kierkegaard: »Section I. Something about Lessing«, in: Howard V. Hong and Edna H. Hong, eds., *Soren Kierkegaard. Volume I. Concluding Unscientific Postscript to Philosophical Fragments*, Princeton: Princeton UP 1992, pp. 61–126.

Features like the *alea/ludus* dimension and the separateness apply to the scientific practice as a whole, irrespective of the single steps in the research process. Other features, such as the *agon* dimension are limited to distinct phases and activities in the research process, in particular the early steps of (i) developing a simulation model that actually runs on the computer and (ii) exploring the model's behavior. (iii) Later on, the search for the explanation of unexpected results constitutes a further phase characterized by the *agon* dimension. A comprehensive list of these phases cannot be given. We have pointed out that the features of play and playful gaming are concealed in the technology and methodology of computer simulation, e.g. the *alea/ludus* dimension, the *agon* dimension and the *mimicry* dimension; the freedom of play is dependent on this technology. Therefore, we argue that the feature of playful gaming cannot be removed from scientific computer simulation. This feature is not dependent on a playful state of mind of the simulating scientist.

Play, Experience and Knowledge in Scientific Computer Simulation

In our frame of reference, playful gaming in computer simulation strengthens the role of experience as an epistemic process in scientific research. The literature on simulation and experiment shows that an important aspect of simulation experiments is gathering experience.[57] In philosophy, experience has long been discredited as a medium of knowledge. Based on Dewey, Schachtner assigns experience an indispensable position as a method of gaining knowledge.[58] She grants an innovative status to experience-based, playful action. In the following, we refer to Gadamer's concept of experience and focus on the playful *hero-v* cycles.

According to Gadamer, experience in general is an essentially negative process, but this negativity has a curiously productive meaning.[59] Our false generalizations are refuted by experience. Our expectations are disconfirmed. What was regarded as typical is shown not to be so. We argue that in this way, the expectations of the simulating scientist are regularly – but not always – disappointed. Sundberg emphasizes the importance of expectations for understanding the output data of simulations.[60] Albeit, each disappointing *hero-v* cycle does not merely reveal the scientist's false beliefs. Rather, she seeks a new, improved, and expanded understanding. We claim

57 See, for instance, Sundberg: »Credulous Modellers and Suspicious Experimentalists?« and Lenhard et al.: »Fluch und Segen«.

58 See John Dewey: *Democracy and Education. An Introduction to Philosophy of Education*, New York: Macmillan 1925 and Christina Schachtner: »Experience and Knowledge. The Creative Potential of Playful Action for Technological Development«, *Concepts and Transformation* 7 (2002), pp. 193–202.

59 See Hans-Georg Gadamer: *Truth and Method*, transl. by Joel Weinsheimer, New York: Continuum 2002, pp. 353–355.

60 See Sundberg: »Creating Convincing Simulations in Astrophysics«, p. 65.

that at the beginning of the playful investigations – still in the phase of the development of the simulation model – the simulating scientist epistemically works with the foregoing analytical model (a formalized theoretical model using mathematical concepts and language). During the playful *hero-v* cycles, this model is superseded successively by a new model. This model rather fulfils the conditions of Nersessian‘s mental models.[61] As Nersessian explains, a mental model is »a structural analog of a real-world or imaginary situation, event, or process that the mind constructs to reason with. What it means for a mental model to be a structural analog is that it embodies a representation of the spatial and temporal relations among and the causal structure connecting the events and entities depicted«.[62] She clarifies that mental models should not be limited to systems of propositions.[63] Rather, they integrate various forms of information – propositions, models and equations.[64] We can also apply Giere's comprehensive concept of model, here.[65] From an epistemological point of view, we find that the practice of computer simulation supports a process of model-based reasoning on the side of the simulating scientist, while the computer itself remains limited to inferential logic and the formalized model implemented into the computer (see Table 1).[66] In the experiential process, the simulating scientist will now and then be surprised. Gradually, she will gain better knowledge on the computer simulation model, not only of itself, but of what she thought she knew before. The mental model will be adapted to this better knowledge while the computer simulation model may remain unchanged for many simulation-runs, except for some initializations. Some results may even force the simulating scientist to see things from a new perspective. As opposed to syntactic and semantic approaches arguing that scientists learn from models by applying deductive and inductive logic,[67] studies on model-based reasoning emphasize the importance of model-based abductions for the generation of new hypotheses.[68]

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61 See Nancy J. Nersessian: »Model-Based Reasoning in Conceptual Change«, in: Lorenzo Magnani, Nancy J. Nersessian and Paul Thagard, eds., *Model-Based Reasoning in Scientific Discovery*, Dordrecht: Kluwer 1999, pp. 5–22.

62 Nancy J. Nersessian: »In the Theoretician's Laboratory: Thought Experimenting as Mental Modeling«, *Proceedings of the Philosophy of Science Association* 2 (1992), pp. 291–301, here p. 293.

63 See ibid.

64 See Nersessian: »Model-Based Reasoning in Conceptual Change«, p. 21.

65 See Ronald N. Giere: »Models as Parts of Distributed Cognitive Systems«, in: Lorenzo Magnani and Nancy J Nersessian, eds., *Model-Based Reasoning: Science, Technology, Values*, Dordrecht: Kluwer 2002, pp. 227–241.

66 See Nersessian: »Model-Based Reasoning in Conceptual Change«.

67 See Mauricio Suarez: »An Inferential Conception of Scientific Representation«, *Philosophy of Science* 71 (2004), pp. 767–779 and Mauricio Suarez: »Scientific Fictions as Rules of Inference«, in: Mauricio Suarez, ed., *Fictions in Science. Philosophical Essays on Modelling and Idealisation*, Routledge: London 2009, pp. 158–178.

68 See Lorenzo Magnani: »Model-Based Creative Abduction«, in: Lorenzo Magnani, Nancy J. Nersessian and Paul Thagard, eds, *Model-Based Reasoning in Scientific Discovery*, Dordrecht: Kluwer 1999, pp. 219–238 and Nersessian: »Model-Based Reasoning in Conceptual

	Simulating Scientist	Computer
Model Type	Mental model	Computer simulation model
Logic Operations	Model-based reasoning, Abductions	Deductions, Inductions

Table 1: The coupled system of scientist and computer from an epistemic point of view

In a nutshell, in the playful *hero-v* cycles the simulating scientist learns from experience. Two models co-evolve: The mental model of the scientist and the computer simulation model. The close interplay of deductive and inductive logic, as well as abductive reasoning, makes these playful *hero-v* cycles epistemically particularly innovative.

In the preceding paragraphs, we have presented our epistemic argument based on hermeneutic phenomenology. It still has to be discussed whether the concept of experience is justified in the context of scientific computer simulation. In the philosophical tradition, the concept of experience has always been related to the notion of contact with the external world. In our context, there is no such contact in any direct way. The experience does not originate in the contact with the target. Rather, there is the contact with the physical materiality of the computer which can be experienced by our senses. We claim that the core mechanism described by Gadamer also holds for experiences in scientific computer simulation: »the negativity of experience has a curiously productive meaning«.[69] We therefore want to defend the concept of experience in the epistemology of computer simulation.

We claim that the role of experience in scientific computer simulation challenges the rationalist superiority of reason thesis. It states that the knowledge we gain in subject area S by intuition and deduction, or already have, is innately superior to any knowledge gained by sensual experience.[70] During the playful *hero-v* cycles, the simulating scientist experiences the negativity in an act of perception of the simulation output that transforms into cognition without understanding. The lack of understanding is based on the epistemic opacity of simulations.[71] More often than not, the computer will provide the result that the expectation of the scientist – her ad hoc hypothesis in a *hero-v* cycle – was wrong. There will not be any explanation given by

Change« and Lorenzo Magnani: »Epistemic Mediators and Model-Based Discovery in Science«, in: Lorenzo Magnani and Nancy J. Nersessian, eds., *Model-Based Reasoning. Science, Technology, Values*, Dordrecht: Kluwer 2002, pp. 305–329.

69 Gadamer: *Truth and Method*, p. 353.

70 See Peter Markie: »Rationalism vs. Empiricism«, in: Edward N. Zalta, ed., *The Stanford Encyclopedia of Philosophy*, http://plato.stanford.edu/archives/sum2015/entries/rationalism-empiricism/ (visited: October 29, 2016).

71 See Humphreys: *Extending Ourselves*; Paul Humphreys: »The Philosophical Novelty of Computer Simulation Methods«, *Synthese* 169 (2009), pp. 615–626 and Lenhard et al.: »Fluch und Segen«.

the computer for this result. *We claim that the negative knowledge gained by sensual experience from watching the simulation results is – only during these* hero-v *cycles – superior to any knowledge the scientist gains by intuition and deduction, or innate knowledge. This is due to the complexity of the computer simulation model where the scientist cannot trust her intuition, deductions or innate knowledge.* The negative knowledge that this experience provides is used to adapt the mental model of the scientist in a process of model-based reasoning. In the long run, the simulating scientist will also obtain positive knowledge and some of her ad hoc hypotheses will be confirmed. Still, there will not be any explanation given by the computer for this result. At this stage of the research process, the experiential processes will lose its superiority.

It is the technology of the computer that allows making these experiences. The mathematical modeler analyzing her model will not be offered that opportunity. She has to exclusively rely on deductive logics and reason. This fascinating aspect, from the point of view of the simulating scientist, is that she can learn from her experience with a model that includes her theoretical conceptualizations. Notably, instead of the sharp dichotomy of thought and experience we find a productive interplay of both in the coupled system of scientist and computer.

Work and Play in Scientific Computer Simulation

In this section, we address the question how work, play and technology are interrelated in scientific computer simulation. We refer to a concept of work from the sociology of work and occupations as the activity of investigating constitutes a form of occupation. Work is a human activity that includes vividly debated and historically contingent features like goal-orientedness, exotelicity, effort, some degree of unpleasantness, use of tools, productivity and payment.[72] Based on this concept of work, we argue that the simulating scientist is working with the computer while playfully gaming. Playful gaming is an essential element of work in scientific simulation. Playful gaming is integrated in the investigative practice of simulative scientific work. To put it differently, a simulating scientist cannot work without playfully gaming.

We claim that the distinctive feature of playful gaming in working is the exotelicity and involuntariness of the play. Therefore, we reject the idea that the scientific practice of simulating is either play or work, or playful or serious. In the same way, we reject the dichotomies play/seriousness, extreme/reasonable and surface/depth

72 See Günter G. Voß: »Was ist Arbeit? Zum Problem eines allgemeinen Arbeitsbegriffs«, in: Fritz Böhle, Günter G. Voß and Günther Wachtler, eds., *Handbuch Arbeitssoziologie*, Wiesbaden: VS 2010, pp. 23–80, here p. 27.

that are put forward by Sundberg to distinguish cultures of simulation from cultures of calculation.[73]

As stated above, the simulating scientist's playful gaming at work is not dependent on her playful state of mind. However, we argue that in those moments when the *agon* dimension is experienced by the scientist, she may move smoothly into a playful state of mind. In their professional training, simulating scientists learn to detach themselves from this experience.

Conclusion

Walter Benjamin's statement, imitation »is at home in the *playing,* not in the *plaything*«[74] reminds us of looking closely at every feature that is related to the anthropologically grounded and culturally diverse phenomenon of play. So, we have argued that Caillois's dimension of *mimicry* is at home in the simulation model – and not in the simulating – while emphasizing that this dimension will not serve as our main argument. Drawing on concepts from the philosophy and sociology of play, this chapter has assessed the (weak) thesis that simulat*ing* in scientific computer simulation is playful investigating.

Our perspective adds to the philosophy and epistemology of computer simulation that perceives the simulating scientist and her computer as a coupled system. Basically, there is a diversity of accounts available to theorize the coupling between the simulating scientist and her computer. The category of play has served us as such an account. Our perspective may be combined with rational reconstructions of the simulative research process. E.g., based on the arguments perspective – neither presupposed nor precluded in our account – Beisbart has argued that »running a computer simulation can be seen as a process in which a coupled system [of scientist and computer] reasons through the reconstructing argument«.[75] His statement refers to a single simulation run. We claim that the kind of coupling can be further specified if several consecutive simulation runs are considered: Running a computer simulation can then be seen as a scientific practice in which a coupled system of scientist and computer reasons through the reconstructing argument by playing a game of types *alea, agon* and *mimicry.* Thus, reason and experience are the sources of the simulating scientist's knowledge. Deductive and inductive logic, as well as abductions, serve the process of knowledge accumulation.

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73 See Sundberg: »Cultures of Simulations vs. Cultures of Calculations?«.

74 Walter Benjamin: »Toys and Play. Marginal Notes on a Monumental Work«, in: Michael W. Jennings, Howard Eiland and Gary Smith, eds., *Walter Benjamin. Selected Writings, Volume 2, Part 1, 1927–1930*, Cambridge, Mass.: Harvard UP 2005, pp. 113–116, here p. 116.

75 Beisbart: »How can Computer Simulations Produce New Knowledge?«, p. 422.

In our outlook, we address the significance of the experiential processes and the questions of play and emotions, of playful investigating in general, and of play as a symbol of this world.

The significance of the experiential processes. We propose to further explore how simulating scientists learn from experience. The co-evolution of the scientist's mental model and the computer simulation model may be investigated by sociologists of science while the philosophy of science may theorize the significance of the experiential processes and search for such processes in other investigative practices. The (codified) methodology of computer simulation keeps quiet about the interplay between reason and experience. Our understanding of the experiential processes may in the long run put us in a position to rewrite some foundational statements on the methodology of computer simulation.

Play and the question of emotions. In section 5.1, we argued that each *hero-v* cycle is accompanied by emotions because each result of a simulation run is perceived as an event. The phenomenology of play (*Spiellust*)[76], as well as phenomenological hermeneutics, suggest that simulating is a rather emotional kind of research.[77] Weinsheimer discusses alternating cycles of hope and disappointment in Gadamer's account of experience.[78] We propose to investigate how emotions influence the simulative research process. On the one hand, we suggest the influence of an emotional stimulus, a stimulus also observed in gaming simulation. On the other hand, we suggest the influence of an emotional bias that obstructs knowledge accumulation from simulation studies, notably if the model produces mediocre results. *Spiellust* makes it difficult to refute the created world.

Playful investigating. We propose to ask if there are other examples of playful investigating, for instance experimentation. What do we learn from recognizing the play in investigative activities? The epistemology of play may reveal investigative practices that have not yet been described and theorized because they have just not been recognized.

Play as symbol of the world. We suggest theorizing about the question of play and computer simulation by studying Fink's works on *Play as Symbol of the World.* His question concerning play is led by a fundamental philosophical problem, the »relation between the human being and the world«.[79] How is this relation changed by way of simulative research?

76 See Fink: *Play as Symbol of the World and Other Writings*.
77 See Gadamer: *Truth and Method*.
78 See Joel Weinsheimer: *Gadamer's Hermeneutics. A Reading of Truth and Method*, New Haven: Yale UP 1985, p. 202.
79 Fink: *Play as Symbol of the World and Other Writings*, p. 80.