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Investigating the Musical Mind:
Situated Cognition, Artistic Human-Robot Interaction Design, and Cognitive Musicology

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I. Convergence and the science(s) of mind

There are different domains in which convergence might take place. Within the arts one can think of the convergence of different forms of expressive media such as music, theater, film, and dance. Concerning media one may think of convergence of technical representations of different kinds of modalities as in multimedia and multi-modal environments. Furthermore, in the sciences one can think of convergence of different approaches to research questions. For example, linguistics, neuroscience, artificial intelligence, philosophy, psychology, and anthropology might converge in a science of mind called "cognitive science." These convergences in the different domains just mentioned are entangled and seem to be based on some common idea. Behind the convergences in (media) technology, art, and science lies the basic idea of "computation." What might be the point of convergence? Might it be the scientific study of mind? This seems to be the case, if one has a look at the initiative "Decade of the Mind Project" (see Albus et al. 2007 and DOM_06 in Singapore 2010 http://www.dom-6.org/). Are different sciences converging on a science of mind? Is a science of mind possible and what might it look like?

On the one hand the humanities, traditionally conceived of as "Geisteswissenschaften" in Germany, are thought of as studying the objective mind or culture: "The nearest English equivalent to the term "objective mind" is "culture" as used in modern cultural anthropology" (Rickman 1967, 276; cf. Wilson 2004 on theories about group minds, collective representations and collective consciousness in biology,

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psychology, and the social sciences).

Science, on the other hand, if interested in the mind, investigates the individual or subjective mind: mental phenomena or faculties such as language and music are conceived of as functions of the neural activity of the (mammalian) brain. Cognitive science, biological anthropology, cognitive psychology, psycho- and neurolinguistics, and the (cognitive) neurosciences should be mentioned in this context. If these sciences get interested in culture, then they conceive cultural phenomena as products of collective brain processes. For example the neuroscientist Wolf Singer (1999, 3) wrote: "Since the phenomena elaborated within the humanities are nothing but products of those collective brain processes that underlie cultural evolution, it should be possible to bring together descriptive systems which trace back brain functions to material components with those that deal with products of individual and collective brain processes." Unfortunately Wolf Singer did not point out to his colleagues, who normally are studying the subjective mind via investigating single brains using imaging techniques and single and multiple cell recordings, how to approach "collective brain processes which underlie cultural evolution" or the objective mind.

There seems to be gap between those sciences concerned with investigating the subjective mind and those concerned with the objective mind. Might there be a convergence of these different approaches?

We are interested in how cognitive science, the study of the subjective mind, and the humanities, the study of the objective mind, might converge in a science investigating the mind encompassing the subjective and objective mind by meeting standards of scientific explicitness and rigorousness (cf. Singerland 2005 on dualism, science, the humanities, body, and culture; Krois 2007 on cognition and culture). Cognitive musicology is introduced as an example within the humanities which uses the paradigm of situated cognition as a framework for the study of the musical mind from a computational point of view.

II. Cognitive Musicology: Situated Cognition and New Media Art

Cognitive musicology investigates the musical mind. This means, music is viewed as a phenomenon of the mind, and the study of cognitive processes (which include emotion and motivation as well as perception and action) forms the starting point for music research. Computation is the key concept for a scientific study of the mind in the paradigm of cognitive science. This concept opens a rich conceptual framework for empirical research, computational modeling and theoretical reasoning. Striving for explicitness, communicability and intersubjectivity in explanations for complex phenomena like the human mind, the concepts 'computation' and 'computational system' with their current explication within automata theory provide an epistemological framework for the foundations of music research. Furthermore, this epistemological framework provides an integrative theoretical framework with powerful ideas from computation or computing to conceptualize music or the musical mind and to guide empirical research and experimental design as well as to interpret empirical data from a unified point of view. Within this conceptual framework the computer is viewed as a metaphor for the mind of man and a tool for research. With the metaphor of man as an animal it provides a computational approach to the musical mind that encompasses evolution, cognition, and culture. Thus, cognitive musicology provides a research program with a unifying framework for connecting empirical research from evolutionary, developmental and socio-cultural and socio-historical perspectives. Within this research program it will be possible to cope with music as a phenomenon of the mind and with such individualistic phenomena as consciousness, intentionality and qualia, i.e. the subjective mind, as well as social, socio-cultural and socio-historical aspects of the mind, i.e. the objective mind. "Musical mind" is conceptualized as embodied and a socio-cultural, situated, conscious, interactive, musical behavior of cognitive agents. Therefore, instead of speaking of consciousness, intentionality, and qualia in exploring the (computational) musical mind the term "conscious musical behavior" is preferred.

In pointing out the important role of neuroscientific, evolutionary and robotic research for the study of mind Thagard (2005) termed the approach of cognitive science CRUMBS, i.e. the computational and representational understanding of the mind, biological and social. In cognitive science cognitivism, connectionism, and interactionism might be distinguished. Cognitivism is associated with knowledge-representation as a classical artificial intelligence technique and logic. Connectionism is related to artificial neural networks and linear algebra. Interactionism which is also termed "embodied cognitive science" or "situated cognition" is strongly associated with robotics. Cognitive musicology can be viewed as (embodied) cognitive science of music within the academic discipline of musicology (see Seifert 1992, 2004; Schmidt 2005, 2008). We use "situated cognition" as an umbrella term for the approach in cognitive science based on the idea that the mind must be studied as an embodied, embedded, and extended phenomenon (Robbins & Aydede 2009). In this context "embodiment" means that the mind is to be explained by referring to its bodily biological basis, with its morphological constraints and the processing activities of a nervous system. "Embeddedness" means that interaction or coupling with the agent's environment must be taken into account. "Extended mind" refers to resources used for computation and storage outside the body of an agent. This perspective is sometimes characterized by the sentence "The mind is not only in the head". To us "situated cognition" expresses at best a conception of cognitive science that enables a convergence of investigations of the subjective and objective mind.

For further empirical research the phenomenon denoted by "music" might be conceptualized as a multimodal, preconscious, preverbal, emotional, motivational and cognitive phenomenon rooted in human social interaction. Stephen Malloch and Colwyn Trevarthen (Malloch & Trevarthen, 2009) termed this general human condition "communicative musicality". The goal of cognitive musicology then is to gain an understanding of the processes or mechanisms underlying musical behavior and the formation, acquisition and change of musical representations. These representations are called internal "schemas." One main research goal of cognitive musicology is to discover the (computational) mechanisms underlying a cognitive agent's conscious musical behavior by combining evolutionary, sociological and psychological perspectives in a computational framework. From the biological perspective neuroethology, evolutionary theory and comparative cognitive neuroscience offer the necessary concepts for studying the development of the (computational) neural mechanisms and especially the (computational) learning mechanisms that serve as the basis for conscious musical behavior and are at the center of the research program of cognitive musicology. Another main task is to identify ecologically valid stimulus configurations for situated systems exhibiting musical conscious behavior when interacting with their environment. It is difficult to think of humans as embedded and situated in a purely biological environment. In contrast, humans inhabit socio-cultural environments. Therefore, the biological-computational research strand on conscious musical behavior has to be complemented by research on socio-culturally situated interaction and collective representations of the domain under study, which might be called "external schemas," In investigating internal and external schemas it is necessary to develop relevant units of functional analysis encompassing the social, psychological and neurological level for studying (computational) mechanisms. Socio-cultural situatedness as well as the research aimed at discovering ecologically valid stimulus-configurations are best studied by combining empirical methods and computational modeling in research on human-computer and especially human-robot interaction in new media art. Artistic human-computer interaction and artistic human-robot interaction are intended to serve these goals. Using robots in this context studying interaction, embodiment and situatedness by computational modeling of the "musical mind" is one important aspect of this approach. In our approach we combine media research and situated cognition using new media art environments as "laboratories" for empirical research and the study of internal and external schemas via human-robot interaction. For the sake of brevity "new media" is characterized by immersion and interaction (Manovich 2005) and therefore new media art is characterized as art using digital systems for enabling immersion and interaction in artistic and entertainment contexts (cf. Seifert, Kim, & Moore 2008).

III. Cognitive Musicology: Social Schema Theory and Artistic Human-Robot Interaction Design

In brain theory and cognitive science Michael A. Arbib's (Arbib 2004) schema theory is the most promising and advanced framework doing justice to collective-external and individual-internal representations of phenomena commonly referred to as "music" and "language." Social schema theory (Arbib 1985; Arbib & Hesse 1986; Arbib 2002) is part of Michael Arbib's schema theory which he introduced in the 1980s to tackle with the dynamics of cognition. In his schema theory Arbib combines the idea of the feedback loop from control theory with the idea of a program from computer science. The main idea behind schema theory is to provide a framework for exploring the dynamics of cognition which is embedded in an action-perception cycle with computational models relating the cognitive or functional and neural or structural levels of processing (Arbib 2004). Normally one should carefully distinguish between schemas as “internal entities” and their description through schema theory, i. e. schemas as formal, external models such as computer programs or analytical mathematical expressions provided by cognitive scientists. Schemas are functional units and schema theory is a topdown approach to brain functions. Basic schema theory (with perceptual and motor schemas), neural schema theory and social schema theory are further distinguished (Arbib 2002 as conceptual “units” of schema theory. Schema theory can express models of cognitive brain functions such as language and music. Schema theory also provides an explanatory framework for the acquisition, development and change of schemas and as such it is a learning theory, too. Simplifying the picture of schema theory: Basic schemas for cognitive processes provide the bridge to neural schemas which describe the neural realization of mental processes as brain functions.

Instantiations of basic and neural schemas are dynamic processes “inside the head” of an individual. Basic schema theory mediates between neural schema theory and social schema theory. Social schemas are “outside the head.” They should not be confused with external schemas as models of internal schemas provided by a cognitive scientist. On the contrary, social schemas “... represent the collective effect of behavior governed by related schemas (in the sense of basic schema theory) in the individuals of a community” (Arbib 2002, 426).

Social schema theory provides the best starting point for cognitive science as situated cognition, i. e. for studying the embodied, embedded, and extended mind. It offers the possibility to relate the study of socio-cultural phenomena of collective brain processes to individual brain processes. Furthermore, schema theory is linked, via Michael Arbib's extended mirror-system hypothesis on language evolution, to an evolutionary and neuroscientific explanatory framework for consciousness and the mind (Arbib 2005; Arbib 2006; Rizzolatti & Sinigaglia 2006). Social schema theory as a research program is still in its infancy and a research methodology and further research is urgently needed. The idea to relate social schema theory to artistic human-robot interaction design in new media art as one possible way to develop this program a step further was expressed in my talk “Cognitive Musicology: A Computational and

Comparative Approach to the Musical Mind" at the "Symposium on Multidisciplinary Approaches to Understanding Mind and the Brain."

Artistic human-robot interaction (Seifert & Kim 2008) is based on the idea of new media art as a test bed for (computational) theories of cognition, emotion, and interaction. It exploits the idea that new media art environments are analogous to laboratories and extends the idea of experimental design to new media art environments. So, computational modeling and empirical research could be combined to test theories and collect empirical data in semi-artificial social environments. The main idea behind artistic human-robot interaction design is to combine traditional empirical research using observational studies, (statistical) data acquisition and data analysis techniques with computational modeling. This means that on the one hand one can study humans' social interaction with robots and at the same time implement computational models of interaction and cognition in the robot. On the other hand one can use robot-robot interaction to study the emergence of (auditory) communication (Wischmann 2007). Investigating social schemas, it is necessary to study behavior emerging from interacting entities. Therefore, it is necessary to think of interacting entities more generally and introduce a generic term. The term "agent" might be appropriate. Schmidt defines an agent as "... an entity that can be distinguished from an environment and is endowed with the ability to act within / upon the environment without explicit directing by any other entity, can take in information from the environment (sense the environment), and persists over some time"(Schmidt 2008, 41). After discussing different kinds of agents from classical artificial intelligence and contrasting these with the complete agent concept from robotics, he concludes: "What is radically different from approaches based on classical artificial intelligence, ... is the way to spell out the components of the agent, exploiting instead of abstracting from details of real-world physical interactions (Schmidt 2008, 50). On the one hand, this poses the challenge to incorporate a wide range of research into agent design; ... On the other hand, the chance is offered to put theories within these research fields to real-world tests by building artifacts incorporating the principles proposed, thus eventually stimulating further theoretical development."

As already mentioned, Steffen Wischmann (2007) designed agents to study the emergence of communication including auditory communication between robots in robot-robot interaction. He distinguished three kinds of coupling: a) "neural coupling," i.e. the internal sensor-actuator relation, b) "environment coupling," i.e. the body-environment relation, and c) inter-agent coupling, the agent-agent relation. Sun (2008) makes a classification similar to Wischmann (2007). He (Sun 9) distinguishes four objects of computational cognitive modeling: a) Inter-agent processes corresponding to social and cultural types of analysis, b) agents related to psychological analysis, c) intra-agent processes with a componential type of analysis, and d) substrates concerning the physiological realization. The inter-agent relation—termed "inter-agent coupling" by Wischmann (2007) and "inter-agent processes" by Sun (2008) is of interest when relating schema theory, especially social schema theory, to human-robot interaction design. The inter-agent interaction may lead to analyzable patterns of communicative behavior that can be conceived of as representing emerging social schemas. Social schemas which result from inter-agent coupling are based on "neural and environmental couplings" which corresponds to basic schema theory with perceptual and motor schemas. In this special case study, neural schema theory is not involved because no reference is made to computations carried out by real brain processes.

The same idea, i.e. that inter-agent coupling corresponds to social schema theory, applies to human-robot interaction as well. Therefore, artistic human-robot interaction design permits the collection of data about social interaction and involved semiotic processes in socio-cultural environments. It also opens up the study social schemas and their emergence whilst testing ideas about basic schemas and their instantiations as the underlying processual mechanisms. Furthermore, this approach has heuristic value because it might lead to new ideas about basic schemas for social interaction or inter-agent coupling.

Artistic human-robot interaction design was carried out for the first time in 2009 at the "International Summer School in Systematic, Comparative, and Cognitive Musicology"as a sound installation called "playing_robot" (cf. Buch et al., 2010). Pieter Coussement, a Belgian new media artist, developed the key idea of the installation's scenario: Two robots are playing peacefully until they are disturbed by human visitors. Sounds and the robots' behavior are changed by the human-robot interaction. Three kinds of sounds and behaviors were distinguished. For "computational modeling" an event-driven finite state automaton was used to structure the behavioral responses of the robotic systems (Lego Mindstorms NXT and Khepera III).

Informal observation was used with the goal in mind to develop a coding scheme for structured observation in artistic human-robot interaction. One preliminary insight supports the view of symbolic interactionism and frame analysis from sociology, that humans are guided by social frames in evaluating and exploring situations. Hence, it seems reasonable to assume that there are some basic schema for "artistic situations", "party situations" and "scientific situations" which indicates that psychological and neuroscientific research must be supplemented by social research.

IV. Concluding Remarks

Artistic human-robot interaction design with schema theory might provide a basis for the study of subjective and objective mind using new media art environments as laboratories. The subjective or individual mind is normally studied in cognitive science. The objective mind or culture is studied within the humanities. Cognitive science as situated cognition and the humanities might converge in investigating the mind. Cognitive musicology was given as an example of a possible converging way of studying the subjective and objective mind. The use of robots plays an essential part of such a converging approach. Artistic human-robot interaction design was proposed as a research strategy. Social schema theory was related to artistic human-robot interaction design. First steps carried out from programmatic considerations to empirical research were outlined.

Should the humanities be concerned with robotics? We think, they should because the products and theories of robotics will not only have a strong impact on society and culture but also on the human self-image, i. e. what it means to be human. Especially, concerning art and entertainment, we agree with Bar-Cohen's and Hanson's (Bar-Cohen&Hanson 112) analysis: "Bio-robotics and AI-driven computer animation promise to transform the face of entertainment and art in ways no previous art medium has" and "artistic explorations effect change in the mindscape and in our cultural information landscape. They [i.e. explorations using robots] can forever change our expectations of what robots are and should be, and what humans are and what we may be in the future." (Bar-Cohen & Hanson 114; cf. also the contributions in Lischka & Siek 2006).

There seems to be at least some kind of social and ethical responsibility for the humanities. For example, “The government of South Korea has announced its goal to put a robot in every home by the year 2020. It is also developing weapons-carrying robots in conjunction with Samsung to help guard its border with North Korea.” (Wallach&Allen 5; cf. Arkin 2009, 10-11, 167-71 on ethical control and Samsung Techwin’s SGR-A1). Bearing such goals of governments all over the world in mind, the humanities should actively take part in the formation of a society in which humans are socially interacting with robots or artificial agents in daily life, art, entertainment, edutainment, therapy, and teaching. One presupposition for an active participation is that researchers from the humanities become acquainted with computational ideas in much the same way as artists did in information art (Wilson 2005).

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Abstract

There are different domains in which convergence might take place. Within the arts we can think of the convergence of different forms of expressive media such as music, theater, film, and dance. Concerning media, we also may think of convergence of technical representations of different kinds of modalities as in multimedia and multi-modal environments. Furthermore, in the sciences one can think of convergence of different approaches to research questions. Artistic human-robot interaction design with schema theory might provide a basis for the study of subjective and objective mind using new media art environments as laboratories. The subjective or individual mind is normally studied in cognitive science. The objective mind or culture is studied within the humanities. Cognitive science as situated cognition and the humanities might converge in investigating the mind. Cognitive musicology is given as an example of a possible converging way of studying the subjective and objective mind. The use of robots plays an essential part of such a converging approach. Artistic human-robot interaction design is proposed as a research strategy. Social schema theory is related to artistic human-robot interaction design. The humanities, I think, should actively take part in the formation of a society in which humans are socially interacting with robots or artificial agents in daily life, art, entertainment, edutainment, therapy, and teaching.

Keywords: Media Convergence, Musical Mind, Cognitive science Cognitive musicology, Artistic human-robot interaction design

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