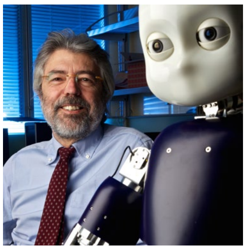
The Hows and Whys of Effective Interdisciplinarity



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The questions posed in the dialogue by Katharina Rolfing, Britta Wrede and Gerhard Sagerer are indeed very important in a period of scientific development where the word "inter- cross- trans-disciplinary" is used more and more often and, in some cases, it is presented as a panacea to revitalize scientific areas (and steer funding sources). The specific case of Developmental Robotics represents, in our view, a genuine and important example where the contribution of different disciplines brings new insight to the scientific question of "what is intelligence" and its engineering translation "how to build intelligent systems" (Sandini 1997; Sandini et.al. 1997). Our comments refer specifically to this aspect of interdisciplinarity focusing on the synergies between artificial systems, neuroscience and cognitive sciences (Vernon, von Hofsten, Fadiga 2011). The main point raised in the Dialogue Initiation is how to form "interdisciplinary thinkers". We believe interdisciplinarity is a "team enterprise" and we would never suggest to a young scientist to "become" interdisciplinary but to "join" an interdisciplinary group bringing to the team his/her own individual (and to some extent unique) expertise and know-how. A good member of an interdisciplinary group is someone with a deep knowledge on a topic relevant to the scientific questions asked and the ability to appreciate the insights from other disciplines, expressed in the specialist language that is associated with those disciplines.

Certainly to facilitate this kind of contribution we need to "provide interdisciplinary training to students" and it is a sensible question to ask when to start and how. Our personal experience tells us that we need to start relatively early i.e. at the master level but this should not be done at the expense of the topics that must form the backbone of an engineer and/or of a scientist. If a computer scientist or a control engineer is attracted by interdisciplinary research he/she has to bring his/her interdisciplinary team deep knowledge about, for example, computational learning or control theory and not trade off these notions for a superficial knowledge of motor control in humans. So at the master level an interdisciplinary thinker has to work mostly on "language sharing" to gain the extra knowledge that allows him/her to be able to understand colleagues coming from different areas but we must not "give the students the impression that they are trained on everything". They need to know how to use their main research tools and to form a solid base of knowledge around those tools. For developmental robotics it could be mathematics, computer science, mechanical engineering or psychology, cognitive science, medicine and so on.

We do not think there is a unique timeframe to become an interdisciplinary thinker but there are two conditions that need to be satisfied in order to develop a true and effective interdisciplinary personality: the first is the research environment where the scientist "lives" which must be interdisciplinary (we will comment on this more) and the second is the existence of a set of scientific questions which are truly shared across the disciplines (by truly we mean questions which are relevant in the respective disciplines). A good example is motor control which offers control engineers the possibility to propose novel theoretical models and neuroscientists the possibility to model how the brain controls movements and, consequently, to give a framework to their experimental activities [Stark 1968]. Starting from the "shared questions" aspect mentioned above, Developmental Robotics can offer many good examples of the problems a psychologist and an engineer have in common. For example the question: "how to learn the affordance of objects" can be addressed by studying human development or by implementing robotic models of affordance. Same questions, different tools.

The important aspect for the synergy to work is that the engineer must be interested in understanding not only "how" affordance can be implemented using the human as a model (a non-human-like model may be interesting all the same) but also "why" it is implemented in that way and the psychologist must be interested not only in saying "why" a given behaviour is present but also "how" it is implemented. In doing so, both can go beyond a purely descriptive model of human behaviour. We think the questions of "how" and "why" need to be answered together because this gives both fields the possibility of explaining the common principles behind, in this case, affordance. Moving from descriptive to explanatory models is, in our view, the main advantage of inter-disciplinary work in developmental cognitive robotics: robots to help with understanding the principles and not (only) to mimic biological exemplars.

While the pivotal issue of "language sharing" can be addressed to some extent by textbooks that provide comprehensive concise integrated overviews of the relevant disciplines (e.g. Vernon et al. 2007 and Vernon 2014), we believe that this kind of deep synergy offering the possibility to exploit jointly the answer to similar questions is best achieved by scientists living in the same environment and sharing space as well as scientific questions.

This we think is the main obstacle to the formation of young scientists contributing and taking advantage of interdisciplinary research.

Among other aspects the most important, in our view, is the possibility to understand which are each other's experimental strengths and weaknesses; the meaning and the limitations of each other's results and their complementarities. These aspects are very difficult to acquire by reading each other's articles and/or participating occasionally in joint workshops as the danger of underestimating the experimental difficulties and overestimating the results obtained is very easy with the consequence of stopping at the "how" without asking the "why" or stopping at the "why" without asking the "how". This hypothetical interdisciplinary environment is, I think, the ideal place to form an interdisciplinary thinker because he/she will be able to continue deepening his/her specific area of interest and to provide it to the "team" without the danger to become an "amateur" scientist or engineer.

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Training Master Students in Cognitive Science

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In their target article, Rohlfing and colleagues expose the considerable challenge of educating young researchers in an interdisciplinary field, considering mostly the doctoral and postdoctoral levels. In the present article, we describe our own attempts at addressing this challenge at the master level.

In the Master program in cognitive science that was created in 2004 by Emmanuel Dupoux and Daniel Andler, and that we now jointly direct, we admit students with a Licence (3-year bachelor degree) in any discipline relevant to cognitive science (psychology, linguistics, biology, philosophy, social sciences, computer science, mathematics, and other math-intensive disciplines such as physics and engineering), and we aim, in 2 years, to turn them into students capable of carrying out a Ph.D. in cognitive science (which, in Europe, usually is a 3-year research project with few or no additional courses). Thus, we face the double challenge of training students to perform research and to do so in an interdisciplinary field. The main stumbling blocks are the sheer amount of knowledge and practical training that they need to absorb in a limited amount of time, and the heterogeneity inherent to the diverse backgrounds of the students. Here are some features of the program that have been designed to address these challenges.

The general philosophy of the program is that the first year (M1) is dedicated to both the reinforcement of each student's initial background and the opening to other disciplines and to cognitive science as such. It is our belief that, whatever students' background, they should keep specializing in it, because in order to do interdisciplinary research, it is not enough to have superficial knowledge of diverse areas, one must be at the top of the field in at least one area. Thus the M1 is divided into five majors reserved for students with the corresponding background: psychology, linguistics, neuroscience, math and modeling, philosophy and social sciences. This also ensures that M1 students can go back to a disciplinary M2 if they want or if they have to, and that students keep a disciplinary label that can be useful later when applying for jobs in institutions that remain structured according to disciplines and where it can be a huge handicap to fall in between established categories.

More specifically, the first year of the program has five components: 1) A core curriculum; 2) concentration courses; 3) introductory courses; 4) advanced courses; 5) internships. The core curriculum is meant to provide all students with a common culture and common methodological tools. This includes catch-up courses in math/statistics and in programming (for those who need it), as well as compulsory workshops on experimental design and on theoretical thinking (based on classic texts of cognitive science and on computational modelling). Concentration courses are specific to each major and only for students with the relevant background. Introductory courses are introductions to