SECTION I:

EVOLUTION AND COGNITION – COMPARATIVE AND DEVELOPMENTAL PERSPECTICES

CHAPTER ONE

ART AND APPRECIATION: UNIQUELY HUMAN?

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Abstract: Close observation of other species has resulted in the realization that most of the characteristics once thought to be unique to Homo sapiens are also found in other species, albeit in a less developed state. This paper addresses recent claims that even artistic creativity may not be unique to human beings. While rejecting the often cited and dubious evidence of animal art admired by humans, it offers an alternative approach which involves clearly operationally defining art, creativity, and aesthetic sensibility in terms of the unique characteristics associated with each. On the basis of these definitions, some evidence is offered to support the idea of an aesthetic sensibility in other species, and one feasible empirical investigation is proposed

What Makes Homo sapiens Unique? The Usual Suspects

Science has a justified reputation for attacking our self-esteem as a species. The first major attack was the Copernican Revolution which moved us and our home from the centre of the universe—and now cosmologists have relegated us to the far suburbs in but one insignificant galaxy among millions scattered over distances we can’t even comprehend. Then a blow was struck even closer to the bone by what Daniel Dennett (1995) calls Darwin’s “dangerous idea” of natural selection. Once we accept this humbling cornerstone of biology, we are tempted to reach out for something, anything, we can claim as uniquely ours—at least in the small corner of the universe to which we have access. Can we at least claim our species is qualitatively different from all the other life forms of which we have knowledge? Descartes infamously considered all non-human creatures as mere automatons, and many are afraid that recent neuroscience discoveries are implying that we too are automatons. Is there any justification remaining for thinking Homo sapiens differ *qualitatively* from other species?

The specific candidates traditionally offered up as evidence of our special status have been systematically eliminated—or at least many feel they have. The four major specific candidates are language, tool-use, cognitive skills at problem solving, and transgenerational transmission of culture. Of course one can choose to operationally define each of these so stringently that only *Homo sapiens* makes the cut, but to do so seems a mere *ex post facto* attempt at saving face.

For example, the degree to which the great apes can understand syntax, or whether they do so at all, is often acrimoniously debated, with researchers such as Francine Patterson, working with the gorilla Koko (Patterson & Linden, 1988), and Sue Savage-Rumbaugh, working with the bonobo Kanzi (Savage-Rumbaugh, Shanker, & Taylor, 2001), claiming to have evidence of sophisticated language abilities including syntactical usage in their protégés, while highly respected linguistic experts such as Stephen Pinker and Noam Chomsky view such claims as exaggerated projections of the researchers' expectations and involvement with their animals. "Possessing a language is the quintessentially human trait: all normal humans speak, no nonhuman animal does." (Pinker, 1995, p. 135)

Nevertheless, it is fair to say that if one doesn't set the bar too high, most researchers have to concede something that could be called 'language ability' in other species. Furthermore, regarding the other three former candidates for human uniqueness, there is plenty of evidence of some degree of cognitive skill at problem solving in many species (Wasserman, and Zentall, 2006), indisputable evidence of animal use of tools, even in birds (Bluff, Weir, Rutz, Wimpenny, and Kacelnik, 2007), and general acceptance of transgenerational transmission of acquired social or adaptive skills in non-human primates (Laland, and Hoppitt, 2003).

However, in more general terms, humankind does seem to be distinct from other species in having science, religion, and art. However science, in the modern sense, was not a characteristic of our species until relatively recent times. And science, in the broad sense of making observations and generalizing from them certainly does exist in primitive form in other species. The strict behaviourist's attempts to explain away apparent empirical reasoning by other creatures has been replaced by widespread acknowledgement of observational learning in animals (Bandura, 1977). Religion can be viewed as a combination of superstitious behaviour and ritualized behaviour, both of which have certainly been observed in other species (Dawkins, 2006). If one accepts this loose definition of science and this interpretation of religion, only art remains as the last bastion of 'hope' for any claim to the qualitative uniqueness of our species.

Some feel that this bastion is being battered by evidence that chimps and elephants and a few other species can, when given the necessary tools, create admirable paintings that are indistinguishable even by art critics from the work of contemporary artists. Whenever a painting by an elephant or a chimp sells for a substantial sum, it makes the news. For example, a painting by Kamala, an elephant at the Calgary Zoo in Canada, recently sold for $1,175. This news is greeted with glee both by those who wish to denigrate contemporary artists and by those who wish to elevate our estimation of animals to a higher plane. However, neither of these groups could be called unbiased evaluators of the significance of such news.

Yet it is a serious philosophical and empirical question whether or not other species demonstrate what could justifiably be called an aesthetic sense, and it is worthwhile to question whether or not aesthetically pleasing paintings created by other species are really valid evidence of such an aesthetic sense—and if they aren't, what really would constitute such evidence. These are the questions addressed in this paper.

To Claim Art As Uniquely Human Requires Defining Art

It is at first surprising that both philosophers of aesthetics and those engaged in doing research in empirical aesthetics rarely address the question of exactly what art is. The primary reason for this is that art, even more than science and religion, is notoriously resistant to definition. This problem stems from the incredible diversity of art forms which seem to have so very little in common. What does found art, such as Marcel Duchamp's urinal have in common with a Rembrandt painting or a Bach fugue or a Bergman film or the unrecorded 1913 *Rites of Spring* ballet performance that caused Stravinsky to flee the concert hall or the Köln Cathedral or the ritual masks of the Dani tribe of Papua New Guinea or the sonnets of Shakespeare or the draping of the Pont Neuf in Paris by Christo?

There is a simple solution to this problem: focus not on the thing called art by someone, not on the object or performance, but rather on the response to it (Stange, in prep). All of the above examples induce in some people what could be called an "aesthetic response", which is precisely what inspires someone to call something 'art'. There is far less confusing diversity in the "aesthetic response" than in what induces it: some of us are or could be 'moved' or 'touched' by all of the above examples, but our experience in each case is surprising similar. This shifting of emphasis from cause to effect may seem like begging the question, not very different from saying intelligence is what IQ tests measure just to avoid confronting what intelligence really is or what people mean when they use the word. However, defining art as what produces an aesthetic response is different. Like being in love, anyone who has had the experience knows what it is. And, from a more scientific perspective, one can cite specific unique characteristics associated with the experience.

There are three empirical criteria that seem to consistently distinguish the aesthetic experience:

(1) It involves an intense emotional response to simulations or imitations of ‘real-life’ events or things. Furthermore, some of these events or things are ones we would find aversive if indeed they were real.

(2) It results in a pleasurable cognitive response to relationships just for their own sake, independent of any apparent utility.

(3) It produces pleasure from pure perception. The perceptual experience seems to be an end in itself.

The seemingly reasonable objection to this definition of art is that one has such aesthetic responses to things we don’t call art; e.g. a stunning landscape or the face of a beautiful woman. This objection misses the point that this is simply a working or operational definition of art. All such definitions are admittedly arbitrary, but nonetheless are considered good and useful if they match up with our general conception of what is being defined. We don’t normally label as art what has been created by chance or by nature. So by eliminating such unintentional causes of the aesthetic response, one arrives at a reasonable working definition for art: art is what produces an aesthetic response and is *not* a product of random or natural events. A painting of a landscape that effects an aesthetic response in someone *is* usually called art. A landscape that effects an aesthetic response in someone *is not* usually labelled art. I realize that even this working definition can occasionally be problematic, but it is far less so than any based on the cause of the experience rather than the experience itself.

However, the first step to answering any question about artistic creativity in another species is to search for evidence of an aesthetic response to *anything*, art or nature. Before one can even consider the possibility of non-human artistic creation, one has to establish evidence of aesthetic appreciation. So now here is a closer look at the three criteria just mentioned.

First to be considered is the paradoxical emotional response we have to what we know are mere simulations or imitations of something, our strong emotional response to what are clearly not “real-life” events. We seek out such experiences even when they would be aversive if real. It makes sense to cry at the death of a loved one. However, we also cry at the death of Romeo and Juliet. Our adrenaline levels surge if we encounter a bear while walking through the woods, but our sympathetic nervous system also is activated by seeing a character in a film suddenly encounter a big, bad bruin. Again there may be a reasonable evolutionary explanation for this. It may be vestigial and residual and no longer particularly adaptive, something like our easily triggered fear of snakes even if most of our species now live where there are no venomous snakes. Or it may serve some function such as training our sense of empathy or rehearsing for dealing with real life events. Nevertheless, it is unique to the aesthetic experience.

Then there is the cognitive response. Much of aesthetic appreciation is largely rational. There is a pleasure inherent in seeing new relationships. A pun or any joke involves surprising us with an unconsidered relationship. A Shakespearean play is all about the complex inter-relationship of fictional individuals. A Bach fugue is about the intertwining of highly abstract contrapuntal and polyphonic sound sequences. Some art is called ‘cerebral’ because the pleasure one gets from it is relatively free of emotion. For example, the murder mysteries of Agatha Christie don’t particularly excite our emotions, for we rarely mourn for the victim, but we derive pleasure from trying to untangle the motivational and situational relationships that led to the crime and finding the overall pattern that points to the perpetrator. There is no question that seeing relationships has tremendous survival value, so of the three markers of an aesthetic response this one has the most obvious evolutionary value.

Finally, one of the most striking things about the aesthetic experience is the pleasure we derive from the pure perception of an object or event. It is entirely understandable that a well “plated’ meal should stimulate our pleasure centres. It makes sense to salivate at the sight of an appetizing meal. The pleasure we derive from perceiving an appetizing dish motivates us to consume the food, which has obvious survival value. It is no accident that some of the so-called “pleasure centres” in the brain such as the hypothalamus are also those that regulate homeostasis and drive us to eat when hungry and drink when thirsty, as electrical stimulation of this structure has repeatedly demonstrated (Bozarth, 1994). However it does not make sense that we derive profound pleasure from a beautiful still life painting of food when we are well aware that the canvas is inedible—and we do so even when we’re not hungry. When one considers the great pleasure derived from something like an abstract piece of music, the mystery is even more overwhelming. Evolutionary psychologists and those researching empirical aesthetics are working hard to explain this phenomenon, but that is not what is at issue here. Suffice it to say that this is an important criterion that distinguishes the aesthetic experience.

To summarize, the aesthetic response is distinguished by emotional, cognitive, and perceptual experiences we find pleasurable and seek out, even though they have no apparent immediate relevance or practical value. And so the critical questions are whether other species also seek out such experiences and whether we can find evidence of this by applying these criteria.

Two Relevant Paradoxes

Before proceeding to the thematic question of whether art is unique to humankind, and how one could possibly answer that question, two apparent paradoxes have to be considered because both are extremely relevant. The first has to do with the famous Turing Test for artificial intelligence, and the second is what I call the “Creative/Critical Paradox”. Both directly relate to any possible test of the uniqueness of art to our species.

The so-called Turing Test is the classic empirical test for artificial intelligence proposed in 1950 by the brilliant mathematician Alan Turing, one of the fathers of computer science. The protocol for the test is as follows. A human ‘judge’ sits at a computer keyboard terminal and communicates by typing messages to two sources located in closed rooms hidden from his view. In one room is a human being who reads and responds to the messages sent from the judge. In the other room there is a computer, allegedly possessing artificial intelligence, which also receives and responds to the messages and questions sent by the judge. If, after extensive questioning and interaction with both the computer and the human, the judge is not able to tell which room contains the human correspondent and which the computer, on a better than chance basis, the computer is said to have passed the test—and can be credited with intelligence equivalent to that of a human being.

The classic refutation of the validity of this test is Searle’s “Chinese Room” thought experiment. Searle (1980) suggests that if you imagine yourself a monolingual English speaker "locked in a room, and given a large batch of Chinese writing" plus "a second batch of Chinese script" and "a set of rules" in English "for correlating the second batch with the first batch", and then a judge who is fluent in Chinese sends you messages, you will be able to ‘reply’ in a way that convinces the Chinese judge that you really know Chinese. You will have passed a Turing Test for Chinese linguistic intelligence without having that attribute.

I find Searle's argument persuasive. I even hold the unorthodox view that Alan Turing wasn't entirely serious and that he actually presented his so-called "test" more as a tongue-in-cheek critique of excessive trust in operational definitions than as a sincerely intended test by which artificial intelligence could be demonstrated. But whatever Turing's motives, his test paradigm and Searle's criticism are just as relevant to the alleged demonstration of artificial creativity as they are to artificial intelligence.

If an independent judge cannot distinguish artworks created by a computer from those created by a human artist, the computer would pass the Turing Test for artificial creativity. Now replace the computer with, for example, an elephant. Imagine you have this elephant in a (big) room painting pictures, while in another room you have an abstract expressionist artist also painting. If, after a substantial number of paintings have been created by both artists, the works are presented to a judge, and that judge cannot consistently distinguish the paintings of the human from those of the elephant, is it not reasonable to say the elephant has passed a variation of the Turing Test modified to determine animal creativity? And, despite the elephant passing the test, isn't the conclusion of animal creativity dubious?

The second apparent paradox is what I call the "Creative/Critical Paradox". It is common to view being critical as easy and being 'creative' as difficult. "Everyone is a critic!" is a common lament, especially by creative people. It is easy to find fault with ideas, but difficult to find new ideas, or so goes the folk wisdom. While there is an element of truth to this common perception of the nature of creativity, it can be misleading.

Creativity has two components: the production of something new and the evaluation of what has been produced. The fact is that production actually is the relatively easy part, while evaluation is the hard part. All good writers know writing is mostly revision. Ideas are a dime a dozen. Good ideas are rare. What distinguishes creativity is the ability to distinguish the wheat from the chaff. I have written software—which I call *Ghostwriter*—that randomly creates a virtually infinite number of syntactically correct sentences. Every once in a great while, like with the proverbial many monkeys at many typewriters with much time on their hands, a sentence sometimes appears that is stunningly beautiful, even profoundly insightful. Whatever creativity I have as a writer resides in my ability to detect these rare gems. The computer program can take care of the production part of creativity, but only a human can take care of the evaluative part.

The creation of art is primarily a matter of evaluating, filtering and then revising. It may be that we often do this evaluation mentally, before physically creating something, before writing a sentence or putting a brush stroke down on canvas. Nevertheless, it is *judgment* that is the critical and distinguishing component of creativity, of the creation of significant art *and* science.

Creativity, like all behaviour, can be schematized as consisting of input, processing, and output. The log-jam in AI development hasn't been at the processing or output parts; i.e., at the productive part of this circuit. It has been at the input part because input involves evaluation. Computers can do logical analysis and output the results. Computers can create images and sound sequences and present them. However, computers *cannot evaluate* their output because they cannot, when their output is sent back as input, *recognize* and *appreciate*—or at least so it seems so far.

If things that produce an aesthetic response result from random events (e.g., the reflections in an oil spill after a rainfall), from evolutionary natural selection (e.g., the male peacock's glorious tail), and from insentient computer algorithms (e.g., a sentence 'written' by my *Ghostwriter* program), should these things be considered creative and assumed to have an aesthetic sense? This is a rhetorical question, for obviously we do not credit happenstance, nature and algorithms with that attribute we call creativity or aesthetic sense.

Aesthetic evaluation depends on appreciation. So these two apparent paradoxes suggest that understanding the nature of appreciation is the key to understanding creativity.

So How To Detect An Aesthetic Response? By Art Appreciation?

To reiterate and summarize, the first place to look for any substantive evidence of an aesthetic sense in other species is not in what they may 'create' (and certainly not the creations judged by human—anthropocentric—standards), for there really is no way to determine if the work is intentional and driven by any aesthetic motives. Nor is it reasonable to focus on creative production as any kind of evidence, for an aesthetically pleasing thing can be created even by random events: What matters is the critical and evaluative aspect of creativity. Thus the logical thing to look for is some evidence of aesthetic *appreciation,* some evidence of an aesthetic response.

The following are the three aforementioned empirical criteria associated with an aesthetic response: 1) an emotional response independent of 'real-life' events; 2) a cognitive response to relationships independent of practical application; and 3) pleasure in perception independent of utility. Human beings clearly search out experiences that induce these responses. Can we possibly determine if other species exhibit these behaviours, behaviours we consistently associate with the aesthetic response?

Emotional responses independent of 'real-life' events? The difficulty in 'reading' animal emotions makes this very problematic, and the question of whether an animal can even distinguish reality from illusion is not easily answered. The closest thing to an empirical investigation of this is the research done with mirrors where there is some evidence great apes (and perhaps elephants and dolphins) recognized themselves as themselves in mirrors (de Waal, 2007). With species that don't show this ability, the observed reaction to simulations of real stimuli seems at first to be accepting the simulations as real stimuli, followed in some species by an indifference to the stimulus that seems to indicate a rejection of it as a mere illusion. An example is how one of my dogs responded to the appearance of canines in television shows. Initially, the sounds of barking and the images (which it should be noted dogs do not perceive as fluid movements because of a different flicker frequency threshold) caused my dog Nick to bark in social response and even look behind the television monitor. Eventually, however, he failed to respond with anything more than a glance at the tube when dogs appeared or barked in some show, even when the barks clearly were ones of distress or aggression.

Cognitive responses to relationships independent of practical application? Again this seems impossible to ascertain. How could we possibly determine if an animal is seeking out intellectual stimulation and challenge? So clearly this, too, seems outside the realm of empirical investigation.

Pleasure in perception independent of utility? Fortunately, this marker *does* seem to be measurable in other species, because it can be inferred if a creature repeatedly seeks out certain perceptual experiences that seem to have no obvious utility. Such behaviour would at least *suggest* a primitive aesthetic sense and *is* testable.

There are three behaviours that could be reasonably considered indicative of pleasure in perception independent of utility, and so perhaps of an aesthetic 'drive':

(1) The first of these is exploratory behaviour: the seeking out of novel experiences for their own sake.

(2) Secondly, there is the seeking of non-sexual and non-utilitarian sensual pleasures.

(3) Finally, the expression of clearly defined preferences for some stimuli over others, without any obvious immediate or evolutionary benefit, would be evidence of purely aesthetic motivation.

In searching for these behavioural markers in another species, I have chosen as my example *canis lupus familiaris*: the domestic dog. The reason for this choice is that our knowledge of the behaviour of dogs is far greater than that of any other species high enough on the evolutionary tree to possibly manifest the criteria behaviours. The domestic dog's intelligence has been estimated (Coren, 1994) to be that of a two-year old human child, and although the great apes exist on a more proximate branch of the evolutionary tree, and are usually assumed to be even closer to us in cognitive ability and behavioural traits, our knowledge of them is far less extensive than of the domestic dog with whom we have empathetically cohabited and observed for at least fourteen thousand years.

So do dogs show exploratory behaviour, the seeking out of experience for its own sake? Obviously they do, and of course exploratory behaviour is also widely observed in many other species. Its evolutionary function is obvious. When sated laboratory rats are placed in a novel maze they don't just lie down and sleep. They spend their time exploring; and if reintroduced to the maze when hungry, they learn the location of the reward faster than rats who hadn't previously had the opportunity to explore the maze (Tolman, 1948).

Do dogs seek non-sexual and non-utilitarian sensual pleasures? Again, obviously they do. There is no survival benefit to being petted, but any dog owner knows their aptly name 'pet' seems to have a biological need for it; and unlike most drives to fulfill a need, the need seems insatiable. A piece of canine wisdom (from which we could learn) is that "when they stop petting you, move on!" Unless we stop stroking them, most dogs seem willing to sit and be petted forever. Grooming behaviour in the primates may seem similar and is usually assumed to serve the useful functions of social bonding and hygiene, but neither seems a particularly likely explanation for the doggie drive to be petted. It is true that some research has indicated cats rub each other's faces as part of social bonding and that humans mimicking this behaviour with their hands produce "affliative responses" in their feline pets. (Schmied et al, 2008) But dogs do not rub each other's backs, and dog trainers and owners know that the canines especially prefer being petted in places where they would not normally be stimulated—and certainly not by others of their species. The most parsimonious explanation of why dogs seek out petting is simply—it just feels good. (Of course, why something feels good which has no utilitarian or apparent evolutionary explanation is a central question in both aesthetics and general evolutionary theory, not to mention neuroscience.)

Nevertheless, it certainly seems that canines do show clearly defined preferences for some stimuli over others without any—at least *obvious*—utilitarian or evolutionary benefit. As every dog owner knows, dogs definitely do have preferences. They have preferred parts of their bodies to be rubbed, preferred places to rest, preferred foods, preferred scents, preferred toys, preferred human companions, etc. Many of their preferences seem to make no sense to us and seem entirely arbitrary and idiosyncratic. (Why my dog Maggie much prefers her fuzzy lion toy to the fuzzy bear toy is a mystery to me.) The meaning and function of preferences is a complex topic of great interest in the field of empirical aesthetics.

One of the ongoing projects of evolutionary psychologists is trying to explain wide-spread human preferences that are now actually maladaptive. For example, a preference for—and thus over-indulgence in—sweet and salty foods is accepted as a major contributor to a variety of medical problems in developed countries. We only have five taste receptors on our tongues and two of these are specialized for inorganic salts and for sugars. Salt is essential to the mammalian diet and once was scarce, so it isn't difficult to understand why we evolved special receptors to detect foods that contain it—and why consumption of it is so pleasing. Similarly, a preference for sweet foods makes perfect sense for two reasons: sugars are one of the most concentrated sources of quick energy and few poisonous plants taste sweet. When salt and high caloric foods were scarce, there was no need for an off switch for our drives to consume them.

When we move deeper into the area of aesthetic preferences the source of these preferences is less obvious, but nevertheless is sometimes discernable or inferable. One example of this is the widespread preference, both in pictures and in the design of parks, for landscapes that resemble the East African savannah which have places to hide safely, yet offer vistas of the surrounding area (Orians and Heerwagen, 1992). The typical urban park is designed as a variety of open and wooded spaces. Also both parks and popular landscape paintings usually contain bodies of water.

Thus it may be that many of our aesthetic preferences for some stimuli over others once had some practical function that has faded away over time and now seems mysterious and inexplicable. Why we prefer the smell of roses over the smell of marigolds may never be explained. Why our dogs couldn't care less about the smell of roses or marigolds, but definitely love the smell of dead and rotting fish, even to the extent of rolling on them to scent themselves, also may never be explained. The suggestion that they do this to disguise their own scent so they can sneak up on prey seems dubious. “Don’t worry, pal, about that big, hairy mammal that seems to be stalking us: my nose tells me it is just a big fish out of water.” I am being facetious, of course, and certainly if the prey were only relying on olfactory warnings, there may be some substance to explaining this behaviour as olfactory masking—although the usual prey species of wolves are mammals, usually more likely to be alerted by their visual systems’ movement detectors than olfactory cues. (One must be careful about facile explanations that simply fit with one’s adopted theoretical framework, e.g., evolutionary biology, and miss more parsimonious explanations. Could not dogs just *like* the smell of rotting fish?)

The virtually indisputable point is that dogs (and of course many animals) show strong preferences for certain—at least *apparently*—non-utilitarian stimuli, which they repeatedly seek out, just as we do when we go to a manicured park or an art gallery. With other species it may be easier to suggest some plausible past or present utility to the preference, but that does not make it qualitatively different from our preferences. For all we know, there very well may be an evolutionary explanation for many humans’ love of baroque music.

A Modest Research Proposal

So let us say an elephant is given brushes and paints and creates a painting. How could one determine if the work is the result of some aesthetic sense or merely a random event? Certainly not by having human beings judge it, for that is incredibly and naively anthropocentric. Just as dogs have very, very different ideas of what smells good than we do, so presumably the elephant artist will have a very different idea of what looks good. They don’t even have the same visual perceptual apparatus as we do: their visual acuity is mediocre; they are dichromats, and what colour they do see is similar to what a human with red-green colour blindness would see.

One has to keep in mind that while we may find something so beautiful and aesthetically pleasing as to want to hang it on the wall, it may be considered repulsive by another species. Because of their aesthetic appeal I have downloaded and saved images of the many beautifully pigmented poisonous frogs that live in the tropics, but it’s reasonable to assume that—unlike me—would-be predators find these frogs very ‘ugly’ because their gaudy colouration is a warning against stopping for a nibble.

Relevant, too, is the lesson to be learned from studies of face recognition in chimps, where initially their ability was judged to be poor. However, the faces presented were human faces, and subsequent studies have shown that even young chimps have excellent face recognition *for their own species*, just not for human faces (Myowa-Yamakoshi, et al, 2005). ("All dem damn humans look alike!") Even sheep have demonstrated finely tuned ability to recognize other individuals of their species, even in photographs (Kendrick et al, 2001).

So if, as I have argued, the one readily measurable indicator of aesthetic sense is aesthetic preference, the following (admittedly quirky) experiment could cast some light on the question of animal creativity and aesthetic sense.

Give a number of elephants (or chimps) paints and canvas, and have them create a number of paintings. Then have an accomplished human artist study these works, and then produce an equivalent number of paintings in the same 'style'. Finally collect a set of paintings by artists working in various styles—of course matched in terms of size and other superficial parameters.

Set up some standard preference paradigm such as has been used in empirical aesthetics research since its inception. Just one of many possible methodologies, widely used for studies of preferential-looking in neonatal humans and animals, is eye and head-tracking of moving stimuli.

Have the animal artists 'evaluate' the works, as operationally defined by, for example, viewing time, to the four stimulus categories: 1) their own productions; 2) other conspecific works; 3) the human stylistic imitations of their works; and 4) a random sample of human art works. Achieving any statistical significance between these four conditions in such a study would be interesting, would be of value in understanding aesthetic preference in non-human species, and could offer some modest supporting evidence for the proposition that abstract, apparently non-utilitarian aesthetic preference isn't uniquely human.

If, for example, a clear preference—or lack of interest in—was only shown for the subject's own productions this would suggest that memory and familiarity were the determining variables. If, as another possibility, a significant preference for both the subject's own work and other conspecific creations was demonstrated, this would seem to indicate some of degree of aesthetic 'judgment' based on that species' perceptual preferences. Of course, neither of these possible outcomes would conclusively demonstrate that the animal is a 'creative artist'! However, it would certainly offer some modest supporting evidence for the proposition that abstract, apparently non-utilitarian aesthetic preference isn't uniquely human. Even if the animal subjects showed a clear preference for the human works over their own creations, perhaps because of novelty, this would be suggestive of aesthetic discrimination.

Conclusion

There is no question that art is one of the greatest achievements of humankind and that no other species has accomplished anything approaching what we have wrought. No whale song approaches the complex beauty of a Bach fugue. No elephant's painting can be compared to the ceiling of the Sistine Chapel. Nevertheless, we exist along the continuum of evolution, and we should be cautious about assuming that huge differences in accomplishment mean that an evolutionary quantum leap has occurred. None of the great apes are ASL signing (or typing) complex periodic sentences, but there is evidence of primitive language ability. We are profoundly different from the other fauna on this planet, but we have repeatedly found that on a very basic level we have more in common with them than previously believed.

The question of whether there is any primitive aesthetic sense in other species, and thus some precursor of human artistic creativity, isn't a trivial one. The recent trend to promote and sell paintings by animals is not motivated by any sincere attempt to answer this question, nor does human evaluation of these works really contribute anything to our understanding. But it has had the positive effect of raising the question. The first meaningful step to a serious scientific investigation of this would be to determine the characteristics that are uniquely associated with an aesthetic sense and aesthetic appreciation, which is itself a worthwhile endeavour. The next logical second step would be to design ways of empirically testing for those characteristics.

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CHAPTER TWO

THE MOSAIC EVOLUTION OF AESTHETIC PREFERENCE.

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Abstract: Evolutionary psychology has provided a fruitful framework for the development of several hypotheses regarding the evolution of aesthetic preference. These accounts generally assume that aesthetic preference is the product of content-specific information-processing mechanisms that evolved in a certain environment to solve particular adaptive problems. In this study, we review results from the fields of empirical aesthetics, neuroimaging, and comparative neuroscience and discuss their implications for approaches to the evolution of aesthetic preference. This review suggests that aesthetic preference is the result of several cognitive and affective processes associated with activity in diverse brain regions, none of which seems to play an exclusive role in the aesthetic experience. Furthermore, we argue that aesthetic preference is the result of a kind of mosaic evolution; whereas some of these underlying processes and their neural correlates must have appeared at some point in the human lineage, others seem to have been inherited from earlier primate ancestors.

Introduction

Our closest living relatives, chimpanzees and gorillas, are capable of carrying out pictorial activities, such as applying paints on canvas (Lenain, 1997). However, this behaviour has only been observed in captive enculturated apes, never in wild animals living in their natural environment. Yet, aesthetic preference – the interest in the beauty of the object produced by oneself or another individual – seems to be completely out of reach of apes and other animals that have been trained to paint. Hence, the capacity to appreciate the beauty of certain forms, colours or objects is usually considered to have appeared at some point during the evolution of human beings, after the divergence of the human and chimpanzee lineages, close to seven million years ago. This discontinuity between human beings, who are capable of viewing the world in terms of beauty and ugliness, and all other animal species, which we assume to be incapable of perceiving the world in these terms, represents one of the greatest challenges to understanding the evolution of this phenomenon. In addition, the earliest archaeological remains that indisputably reveal the existence of aesthetic preference in our ancestors are very recent in evolutionary terms, and they are undoubtedly the product of fully-fledged "aesthetic minds".

The difficulties posed by the lack of solid material evidence pose considerable challenges to provide a sound explanation of the evolution of aesthetic preference. There are, though, at least three reasons that make this such an interesting topic. First, given that there is no obvious continuity with non-human animal behaviour, the capacity to appreciate beauty has traditionally been considered one of the features that identify the human species, distinguishing it from its closest living and extinct relatives. In this sense, it defines and demarcates the boundary of "what being human is". Second, aesthetic preference is not only related to the creation and admiration of some of the most extraordinary manifestations of human culture, such as art and architecture. It is also manifested in many of our everyday activities, such as choosing what clothes to wear, which car to buy, and how to decorate our homes. Finally, we will only have a limited understanding of the capacity to appreciate beauty, or any other cognitive phenomenon, until we have a clear picture of its phylogenetic dimension.

Hence, aesthetic preference – the capacity to value beauty – appears to be a unique phenomenon in the natural world that permeates the life of humans, from the ornamentation of one's own body to the creation of great works of art. In this study, we review some of the hypotheses that have been proposed to explain its evolution, and we point out some of their fundamental postulations. Thereafter we review results from psychological, neuroimaging, and comparative neuroscience studies that we believe can shed light on the evolution of aesthetic preference. Finally, we sketch a new proposal that is coherent with these results and compare this proposal with existing evolutionary approaches.

Evolutionary Psychology of Aesthetic Preference

By providing an explanatory mechanism of the evolution of physical and functional traits, Darwin (1859/1991) opened the door to the foundational ideas on the evolution of aesthetic preference. A good early example of this is Clay's early exploration of possible answers to the question, "Why should emotional response to harmony or rhythm as such, whether in sound, colour or form, have a survival value?" (Clay, 1908; p. 287). He believed that modern humans inherited the ability to appreciate beauty from their earlier ancestors, which were endowed with a more rudimentary sense of beauty. The main selective advantage conferred by this capacity was, according to Clay, the possibility of distinguishing suitable from unsuitable environments:

It does not seem unreasonable to suppose that the instinctive pleasure in harmony is due to the impelling need for suitability to environment; and that to any organism the power of feeling the first sign however faint that it was out of touch with its surroundings, instead of merely proving it by living or dying, would have an inestimable value in the struggle for existence, so that such powers would be quickly increased and developed (Clay, 1908; p. 288-9).

Grant Allen (1880) presented a different proposal, arguing that the starting point for the study of "the primitive source of the appreciation of beauty" (Allen, 1880; p. 30), should be the observation of other animals' behaviour. He noted that most mammals and birds show some sensitivity to natural beauty. However, this sensitivity is restricted in range to sounds made by their own species and the forms and colors of their decorated mates. Reformulating Darwin's (1874/1998) own vision, Allen (1880) suggested that when the first humans appeared, after the differentiation of their lineage, they possessed only an elementary sensibility for the beauty of form, symmetry, and colour. The fully conscious manifestation of this capacity would occur solely in relation to physical features of their conspecifics of the opposite sex. The expression of this sensibility in relation to objects, such as flowers, fruits, and feathers, would have been very limited. Only with the continuing evolution of human beings did this primitive conception of beauty broaden to include the sensibility for natural and cultural elements (Allen, 1880).

The virtual disappearance of Darwinian thinking in all fields of psychology and other social sciences at the beginning of the twentieth century (Plotkin, 2004), also brought studies into the evolution of aesthetic preference to a full stop. In fact, researchers only resumed researching the topic when Wilson's (1975) Sociobiology and Eibl-Eibesfeldt's (1988, 1989) Human Ethology were introduced. However, the work carried out during the past two decades by evolutionary psychologists has proven to be the most fruitful, thoughtprovoking and recognized. Building on the early work, a large number of the proposals presented by these authors stressed the adaptive value of recognizing suitable environments or mates (Smith, 2005).

Orians (2001) argued that aesthetic experiences have been molded by natural selection through the adaptive advantages conferred by emotional responses during decision-making and problem-solving: “Survival is enhanced by making better decisions about avoiding environmental hazards, where to find and how to choose food, places in which to live, and associates for various activities, including reproduction” (Orians, 2001; p. 25). Current aesthetic experiences involve emotional responses that have been shaped for generations because of the advantages they conferred in determining which elements in the environment require attention and the appropriate responses to them. From this perspective, natural selection would have endowed humans with a series of specific adaptations to assess the suitability of certain landscape features, animals, fruits, or natural indicators of the necessity to modify certain behaviours. These mechanisms would aid in the solution of various adaptive problems, such as the identification of safe and resource-rich places in which to settle, animals that may constitute a source of food or danger, fruits and other nutrient-rich vegetables, or the first indicators of rain, the sunset or the sunrise (Sánchez, 2005).

Given that our Pleistocene ancestors were hunter-gatherers living in groups that moved and resettled frequently through savanna-like landscapes, it is assumed that habitat selection was especially important to them: “Our aesthetic reactions to landscapes may have derived, in part, from an evolved psychology that functioned to help hunter-gatherers make better decisions about where to move, where to settle, and what activities to follow in various localities” (Orians & Heerwagen, 1992; p. 557). Kaplan (1992) argued that selective pressures in early humans favoured exploration and gathering information about the environment while not moving too far from what was familiar, and emphasized that selection must have molded this capability to assess environments to be fast and unconscious. As noted by Kaplan (1987; p. 25), the preference for natural sceneries, environments, and landscapes is not a special case of aesthetics, but more likely the basis on which some of the more traditional aesthetic domains are anchored.

Alternatively, Darwin (1874/1998) and Allen’s (1880) notion that the evolution of the appreciation of beauty is related with mate choice was recently reintroduced and updated by Miller (2001). He views art and aesthetics as biological adaptations acquired throughout human evolution:

It evolved through sexual selection to serve the same courtship functions as almost all other examples of organic beauty and complex behavioral signals observable in nature. Such ornamentation often evolves as a reliable, costly indicator of the signaler's good health, good brain, and good genes. This leads to the further proposal that many design features of art function as indicators of the artist's virtuosity, creativity, intelligence, conscientiousness, and other important heritable mental and physical traits. This 'aesthetic fitness' view suggests that aesthetic judgment is a natural part of mate choice and social cognition, in which an art-work is viewed as the extended phenotype of the artist (Miller, 2001).

He suggests that our aesthetic preferences evolved favouring works of art that could only have been created by high-fitness artists. Thus, we are inclined to consider people who are able to produce high qualitative work as attractive due to our evolved preferences for what is difficult, rare, skillful and costly. This serves as an indicator of such qualities as health, energy, creativity, access to rare materials, good learning abilities, intelligence and coordination, among others (Miller, 2001). From this point of view, evolution shaped our aesthetic preference to distinguish difficult from easy, rare from common, skillful from careless, and costly from cheap, by means of a domain-specific adaptive mechanism.

Although these approaches posit diverse selective advantages driving the evolution of aesthetic preference, their notions of aesthetic preference and its evolution exhibit certain common features. These features are most clear in approaches framed within what has been called narrow evolutionary psychology (see Bechtel, 2002), which follows the reasoning and methods as developed by Tooby and Cosmides (1992). Whether aesthetic preference is considered to have provided greater advantages in recognizing suitable environments or suitable mates, it is usually considered to be a single integral capacity. It has been conceived as a distinct mechanism that evolved because it solved a specific adaptive problem. As Kogan (1994) states, "Over evolutionary time, we should have genetically acquired a set of beauty detectors as an evolved psychological mechanism" (Kogan, 1994; p. 144). In fact, most evolutionary psychologists favour some kind of modular conception of cognitive processes: "From an evolutionary perspective, the human cognitive architecture is far more likely to resemble a confederation of hundreds or thousands of functionally dedicated computers, designed to solve problems endemic to the Pleistocene, than it is to resemble a single general-purpose computer equipped with a small number of general-purpose procedures such as association formation, categorization, or production-rule formation" (Tooby & Cosmides, 1995; p. 1189). Therefore, aesthetic preference is conceived as a distinct cognitive mechanism dedicated to the performance of a specific function. It is fair to say that this represents the views of most evolutionary approaches to aesthetic preference, though they may vary in the way they characterize modules (Barrett & Kurzban, 2006).

A second common assumption is to consider that aesthetic preference, together with many other cognitive mechanisms, appeared in response to the Pleistocene savanna-like environments of our hunter-gatherer ancestors. This kind of environment is sometimes generically referred to as the environment of evolutionary adaptedness. The comprehension of the evolution of aesthetic preference requires examining the adaptive problems posed by this kind of environment: "Thus, to map the structures of our cognitive devices, we need to understand the structures of the problems they solve, and the problem-relevant parts of the hunter-gatherer world" (Tooby & Cosmides, 1995; p. 1194). Hence, "If art evolved in our lineage over the last one or two million years, there is little reason to expect proto-art abilities in living non-human primates such as chimpanzees, which split off from us at least 5 million years ago" (Miller, 2001).

Tooby and Cosmides (2001) summarized the general view of evolutionary psychologists with great clarity: "Our species-typical neural architecture is equipped with motivational and cognitive programs that appear to be specially designed to input fictional experiences and engage in other artistic activities" (Tooby & Cosmides, 2001; p. 10). Although they consider the possibility that aesthetic preference, together with other aesthetic and artistic capacities, is an accidental result of brain and cognitive mechanisms adapted to perform different functions, they argued that aesthetic preference was directly selected for the specific functions and adaptive value this capacity conferred our hunter-gatherer ancestors: "We expect that humans have evolved motivational systems (or systems of aesthetic preference) that are designed to find rewarding the kinds of actions and experiences that would have been adaptive for our ancestors".

In contrast to this view of the evolution of aesthetic preference, we will review literature that suggests that aesthetic preference is best understood as the result of interaction among multiple component processes, none of which is exclusively dedicated. Furthermore, we will argue that these components seem to have different evolutionary histories. While some seem to be the result of evolutionary episodes which occurred throughout human evolution, others seem to be inherited from distant primate ancestors. We believe that the human capacity to appreciate beauty cannot be explained by a single adaptive function or selective pressure. On the contrary, we will conclude that aesthetic preference is the result of a mosaic of evolutionary processes. Multiple selective pressures influenced different component processes, conferring diverse selective advantages. It is possible, moreover, that this might have occurred at various moments throughout our species' evolution, both before and after humans and chimpanzees split. It is not unconceivable that humans share some of the cognitive and neural underpinnings of aesthetic preference with other primates, thus indicating it may in fact predate humans themselves.

Cognitive and Affective Processes Underlying Aesthetic Preference

Although the idea that some cognitive and neural mechanisms underlying human capacities, such as aesthetic preference, may be shared with non-human primates initially seemed far-fetched, it is currently being explored in language and morality. Some of the cognitive processes involved in language comprehension and acquisition, presumed to be specifically human traits, have also been identified in monkeys (for reviews of this research see Tincoff & Hauser, 2005; Weiss & Newport, 2006). Similarly, Flack and de Waal's (2000) division of human morality into four building blocks (sympathy related traits, norm related traits, reciprocity, and getting along) allowed them to identify their possible evolutionary roots in our primate relatives. This suggests that not all the constituent cognitive operations subservient to human morality and language appeared after the human and chimpanzee lineages diverged. On the contrary, it implies that they appeared long before humans, and that human language and morality evolved, at least in part, by recruiting pre-existing building blocks.

In this section we will review recent psychological models of aesthetic preference based on experimental data, together with neuroimaging studies, which suggest that conceiving aesthetic preference as a cognitive process, a computational programme, or a single mechanism, is a misleading over-simplification. To consider language, moral reasoning, or aesthetic preference, as single and unitary cognitive processes may suggest that each of these cognitive faculties constitutes a single and distinct piece of computing machinery, resulting from one or very few evolutionary episodes and selective pressures. However, as we just mentioned, viewing cognitive mechanisms as the result of the modification and novel combination of previously existing subcomponents has proved very fruitful to understanding their structure and evolution (Marcus, 2004). Evolutionary approaches to human behaviour and cognition must not lose sight of the fact that admiring the beauty of a sculpture or a painting, or creatinga piece of art, are the result of the interplay of different cognitive processes, probably none of which are exclusive to the task. This has been highlighted by recent models of aesthetic experience that integrated the results of numerous studies that explored the influences of different factors on aesthetic preference (Chatterjee, 2003; Leder, Belke, Oeberst, & Augustin, 2004).

Leder and colleagues' (2004) model proposes that cognitive processes involved in aesthetic preference occur in five stages. The first of these stages includes processes related to perceptual analysis, such as organization, grouping, symmetry analysis, as well as the processes related to complexity and other perceptual variables that are known to affect aesthetic preference. The analysis of the stimuli on the grounds of familiarity, prototypicality and meaning is performed in the second stage, related to the implicit and automatic integration of information with pre-existing memory structures. An explicit classification is performed in the third phase, which includes cognitive operations related to the style and the content of the stimulus. This is followed by the specific art- and self-related interpretations, under the cognitive mastering stage. Finally, the model produces two different outputs: A cognitive state, the outcome of earlier cognitive stages, and an affective state, a result of continuous interactions between the aforementioned processes and diverse affective mechanisms. The cognitive state is the grounds for the aesthetic judgment, while the aesthetic emotion is grounded on the affective state.

Chatterjee's (2003) proposal presents a slightly different view. He suggests that, in the case of visual arts, during the initial stage, early visual processes divide the stimulus into simple components, such as colour and form, which are extracted and analyzed in different brain regions. In a subsequent stage, intermediate visual processes group certain elements and segregate others to form coherent representations. In late visual stages, certain regions of the stimulus are selected for processing in greater detail. At this moment, information stored in memory becomes active, objects are recognized and associated with their meanings. This visual analysis elicits emotions associated with the aesthetic experience and provides the foundations to formulate aesthetic judgment. This model also includes feedback of information, via attentional processes, from late visual levels and affective systems to early visual processing stages.

Whereas Chatterjee's (2003) proposal can be considered a neuroscientific model of aesthetic preference for a broad range of visual objects, Leder and colleagues' (2004) proposal was conceived as an information-processing model of aesthetic judgment of visual works of art (Vartanian & Nadal, 2007). Despite these conceptual differences, both models consider that aesthetic preference involves diverse cognitive and affective mechanisms. They both acknowledge the importance of early and late visual processes in the generation of an emotional response and arriving at a decision. These models also consider the influence of complexity, order, grouping and many other variables familiar to experimental aestheticians, as well as the interaction between affective and cognitive processes such as the activation of memories and the search for the stimulus' meaning. Additionally, both models suggest two different outputs: An emotional response or aesthetic emotion versus a decision or aesthetic judgment. Hence, it is currently very clear that this capacity relies on a variety of cognitive and affective processes. Some of these are related to perceptual analysis, others to recognition and related mnemonic processes, and some to decision-making, or analysis of the affective value of the stimulus.

With the increase of our understanding of these constituent processes, together with advances in the methodology and precision of neuroimaging techniques, researchers have become interested in describing the underlying neural mechanisms related to cognitive and affective processes involved in aesthetic preference. There are currently four published neuroimaging studies dealing with this issue. Kawabata and Zeki (2004) used functional magnetic resonance imaging (fMRI) to register the brain activity in participants while they rated the beauty of a series of visual stimuli. The results of this study revealed that the activity in the orbitofrontal cortex was greater for stimuli classified as beautiful, whereas activity in the motor cortex was greater for stimuli rated as ugly. Also by means of fMRI, Vartanian and Goel (2004) found that activity in the caudate nucleus, the anterior cingulate gyrus and occipital gyri increased with the preference of the participants for the presented stimuli. Jacobsen, Schubotz, Höfel, and von Cramon (2006), who used the same neuroimaging technique, identified a relation between aesthetic preference and neural activity in the temporal pole, the lateral prefrontal cortex and the frontal pole. Finally, using magnetoencephalography (MEG), Cela-Conde, Marty, Maestú, Ortiz, Munar, Fernández *et al.* (2004) found an increase in the activity of the left dorsolateral prefrontal cortex between 400 and 1000 milliseconds after the presentation of stimuli rated as beautiful by their participants.

It might seem surprising that four studies designed with the same objective – to identify the neural correlates of aesthetic preference– would lead to such diverse results. However, it was not claimed in any of the studies that the identified regions acted in isolation. In fact, the divergence in their results represents a clear testimony to the true complexity of processes underlying aesthetic preference. This capacity actually relies on the coordinated function of multiple cognitive and affective systems. We have previously suggested that certain aspects of the experimental designs and procedures might have led each of the four studies to register only a partial image of the complex underpinnings of aesthetic preference (Nadal, Munar, Capó, Rosselló, & Cela-Conde, 2008). Based on the results produced in the four studies and current knowledge of the neural correlates of cognitive and affective processes, we suggested that affective processes involved in aesthetic preference seem to be mediated by certain regions of the orbitofrontal cortex (Kawabata & Zeki, 2004), the caudate nucleus, and the anterior cingulate cortex (Vartanian & Goel, 2004). The recognition of the visual stimulus and the attribution of meaning in aesthetic preference seem to be related to activity in the temporal pole (Jacobsen *et al.*, 2006). The actual decisions required by the experimental settings are apparently mediated by the lateral prefrontal cortex and the frontal pole (Cela-Conde *et al.*, 2004; Jacobsen *et al.*, 2006). Finally, there is evidence of top-down enhancement of early visual processes carried out in the occipital cortex (Vartanian & Goel, 2004).

Clearly, psychological models of aesthetic preference that account for a broad range of experimental findings and neuroimaging studies converge on the notion that aesthetic preference is not a single cognitive process, nor does it rely on a single, unitary mechanism. They rather indicate that it is the result of several cognitive and affective processes related to different aspects of the stimulus. Moreover, neither psychological experiments nor neuroimaging studies have uncovered evidence for cognitive or neural mechanisms especially devoted to, or exclusively involved in aesthetic preference.

The Evolution of the Neural Correlates of Aesthetic Preference

Neuroimaging experiments have revealed that a broad network of brain regions support the multiple cognitive and affective processes that are involved in aesthetic preference. It is very possible that not all the neural structures involved in aesthetic preference, and the functions they perform, have undergone the same degree of transformation since the appearance of the human lineage. We have contended that together with the comparative method, knowledge of the neural correlates of aesthetic preference can be used to determine whether brain regions involved in aesthetic preference show any kind of distinctive features in humans, or whether, on the contrary, they remained unchanged since the divergence of our species from its closest living relatives (Nadal, Capó, Munar, Marty, & Cela-Conde, in press).

The comparative study of species provides a means to clarify the phylogenetic relations among them and to shed light on the evolutionary history of the traits that characterize them. The comparative method relies on two fundamental methodological tools: The distinction between homology and homoplasy, and the principle of parsimony. A trait is said to be homologous when it appears in two species because it was inherited from a common ancestor, such as the five digits in different species of mammals. Conversely, a homoplasy is a trait exhibited by two species as the result of independent evolutionary processes, like the wings of sparrows and bats. The principle of parsimony is primarily used as a means to organize evolutionary lineages of closely related species, especially in reference to traits that are not reflected in fossil remains. This principle states that if a trait appears in two closely related species, such as human beings and chimpanzees, or human beings and Old World monkeys, it can be assumed to be a homology. That is to say, the presence of the same character in these species is more likely to be the result of the inheritance from a common ancestor than of its independent evolution in both species. Implementing the principle of parsimony, in this section we will review findings from comparisons between human and non-human primates' brain structures and processes shown to be involved in aesthetic preference by the aforementioned neuroimaging experiments. We need to point out a caveat before we proceed. As Sejnowski and Churchland (1989) have noted, the brain is organized in several hierarchical levels, including systems, maps, networks, individual neurons, synapses and molecules. As with any other cognitive operation, there is no way of determining which level of analysis is the most relevant to the study of aesthetic preference. Furthermore, the evolution of such a capacity may result from alterations in any set of these levels. However, available knowledge of the neural underpinnings of aesthetic preference is limited to the levels of systems. The little knowledge we have about human brain evolution makes it difficult to present meaningful hypotheses about modifications at most of the other levels. Hence, our analysis will be restricted to the higher levels in the organizational hierarchy of the brain.

Visual Processing System

As we saw above, the study performed by Vartanian and Goel (2004) revealed that visual processing activity in the occipital gyri was greater when participants awarded high preference ratings. Several studies have shown that throughout human evolution, brain regions involved in visual processing have expanded to a lesser degree than the whole brain has (Rilling, 2006; Schoenemann, 2006), suggesting a trade-off towards cognitive processes which are not directly bound to sensory information. Turning to a finer level of analysis, the retinotopic organization and functions of brain areas involved in early visual processing, known as V1 and V2, are conserved to a great extent in human beings (Orban, Van Essen, & Vanduffel, 2004). However, certain aspects of the human area V1 are derived. For instance, Preuss and Coleman (2002) found that humans differ from monkeys in certain features related to the cortical representation of the magnocellular system. It seems that some of these features occurred initially in the common ancestors of African apes and humans, while others appeared to have evolved exclusively along our lineage. Given that the magnocellular visual processing stream is involved in the analysis of luminance contrasts, movement, perspective, the relative size of objects and depth perception, it is reasonable to assume that the changes that appeared in this stream had an impact on these perceptual processes.

Whereas homology in monkeys and humans is relatively easy to study in primary visual areas, this becomes increasingly difficult as one moves to higher levels of the visual system. Various studies reviewed by Orban and colleagues (2004) suggest that the ventral and dorsal visual information streams have been transformed to different extents throughout human evolution. Specifically, the areas that constitute the ventral stream, related to the representation and categorization of objects, have experienced a smaller expansion than those that are part of the dorsal stream, involved in the representation of space and the analysis of visual information to organize action (Orban *et al.*, 2004). Barton (2006) noted that the fact that parietal areas of the dorsal stream receive information only from the magnocellular system, supports the aforementioned notion that cortical representations of information fed by the magnocellular system have been the target of special modifications throughout human evolution. The studies that have shown brain activity in homologous brain regions in humans and monkeys during the perception of symmetry (Sasaki, Vanduffel, Knutsen, Tyler, & Tootell, 2005), the representation of visual objects (Munakata, Santos, Spelke, Hauser, & O'Reilly, 2001), and their classification (Sigala, Gabbiani, & Logothetis, 2002), support the idea that the ventral visual processing stream is relatively conserved in human beings.

Temporal Poles

Jacobsen and colleagues' (2006) neuroimaging study mentioned above revealed that the task of rating the beauty of geometric visual stimuli is related to greater activity in the left temporal pole than the task of rating other visual features. The authors suggested that the function of this region was to generate an affective and semantic context, based on previous experiences, with which to frame decisions on the beauty of visual stimuli.

Rilling and Seligman (2002) compared diverse aspects of the temporal lobes of a broad sample of primates, including humans. Their results revealed that the temporal lobe has grown in surface, volume and white matter proportion throughout human evolution. This suggests that, to a certain extent, connectivity patterns have been reorganized since the appearance of the human lineage (Schenker, Desgouttes, & Semendeferi, 2005). Rilling (2006; Rilling & Seligman, 2002) has suggested that this reorganization, which is evident mainly in the left hemisphere, could be related to the appearance and expansion of regions of the temporal pole supporting linguistic functions. Specifically, the ventral visual processing stream seems to have shifted further ventrally to allow the expansion of speech and language related areas on the lateral surface of the temporal lobe, which seem to bear a close phylogenetic relation to those underlying the processing of species-specific calls in monkeys (Gil-da-Costa & Hauser, 2006).

In relation specifically to the temporal pole itself, there is evidence indicating that most of the functions it supports in our species are primitive. It is known that in humans this region is involved in the use of prior experiences to generate a semantic and affective context, which enhances the interpretation of the information being processed. Studies in comparative neuroanatomy have provided evidence that this region performs similar functions in other primates. Kondo, Saleem and Price (2003) showed that the temporal pole of monkeys is richly connected to orbital and medial prefrontal cortical nets, suggesting its involvement in the integration of affective, mnemonic and sensory information. Furthermore, the results of Croxson, Johansen-Berg, Behrens, Robson, Pinsk, Gross *et al.* (2005) revealed that the connectivity patterns between temporal and prefrontal cortices in humans and macaques are very similar.

Finally, it has been shown that the temporal pole plays an important role in object recognition. Lesions to this region especially impair the recognition and recall of specific entities, and familiar objects and faces (Nakamura & Kubota, 1996). Experimental results support the notion that this function might constitute a homology in monkeys and humans. Vogels (1999), for instance, demonstrated that neurons in the anterior temporal cortex of monkeys are involved in the processing of visual information related to objects, and that they are sensitive to the presentation of exemplars of a learned category. Likewise, other studies reviewed by Nakamura and Kubota (1996) suggest that lesions to the monkey temporal pole can lead to deficits in the recognition of the experimenter’s gloves, food or live snakes, but not in the discrimination of unfamiliar objects or patterns.

Dorsolateral Prefrontal Cortex

The studies performed by Cela-Conde *et al.* (2004) and Jacobsen *et al.* (2006) revealed an increase in the lateral prefrontal cortex while participants rated the beauty of paintings, photographs and geometric designs. As mentioned above, this activity could be related to the actual decision about the beauty of visual stimuli presented in both studies.

Contrary to common assumptions about the prefrontal cortex, and specifically its lateral region, there is evidence that to a great extent its organization is functionally and cytoarchitectonically conserved in humans. Petrides and Pandya (1999) compared the connectivity patterns and cytoarchitectonic organization of the dorsolateral prefrontal cortex, which encompasses Brodmann Areas (BA) 8, 9, and 46, of macaques and humans. Their study did not reveal any new cytoarchitectonic areas in the human brain. In fact, these areas exhibited very similar features in human and macaque brains, whereby in both species the same traits could be used to distinguish the areas within this region. The degree of homology of neural architecture of this region is such that the same subdivisions of the areas can be found in both species (8Av, 8Ad, 8B, 9/46d and 9/46v). The comparative analysis of the ventrolateral prefrontal cortex of humans and macaques performed by Petrides and Pandya (2001) revealed a similar image of BA 47/12 and BA 45. The cytoarchitectonic criteria used to identify both areas in monkeys and humans were the same, as well as those used to differentiate them from dorsolateral cortex areas. Once again, even the finer subdivisions of area 45 (45A and 45B) were identifiable in both species.

Although the brain organization of monkeys has been studied mainly by means of lesion studies and that of humans by means of neuroimaging studies, these two species also present functional homologies related to the lateral prefrontal cortex. As noted by Petrides (2005), the lateral cortex of humans and monkeys is functionally organized along a caudal-rostral axis and a dorsal-ventral axis. Specifically, in both species the caudal region of the prefrontal cortex (BA 8) contributes to the flexibility of attentional shifts between stimuli and the selection of responses depending on learned conditional rules. At the rostral end of this axis, the mid-dorsolateral cortex (BA 46 and BA 9/46) is involved in working memory tasks that require monitoring the selection of stimuli or the occurrence of expected events. The contribution of the mid-ventrolateral prefrontal cortex seems to be important for other executive functions, including the selection and comparison of representations of stimuli stored in short-term and long-term memory, as well as judgments based on them (Petrides, 2005). Given that neuroimaging studies carried out on human participants and lesion studies on monkeys converge in their results, it seems adequate to consider that the functional and cytoarchitectonic of the human lateral cortex is a primitive trait.

However, it is true that certain aspects of the lateral prefrontal cortex distinguish humans from other primates. For instance, it is obvious that the involvement of these functions in certain human cognitive abilities, such as language, or even aesthetic preference, does not occur in non-human primates. Second, the kind of information on which these functions are performed also seems to differ. This was demonstrated by Denys, Vanduffel, Fize, Nelissen, Sawamura, Georgieva *et al.* (2004), who utilized fMRI to show that activity in the prefrontal cortex while monkey and human participants viewed visual objects was much stronger in the former than in the latter. The authors interpreted this finding as evidence of the multisensory nature of the information reaching the prefrontal cortex of humans, which contrasts with the primarily visual information that reaches the prefrontal cortex of monkeys.

Anterior Cingulate Cortex

The studies carried out by Vartanian and Goel (2004) and Jacobsen *et al.* (2006) identified activity in this region while participants rated visual stimuli as beautiful or expressed high preference for them. Above, we suggested that the involvement of this brain region in aesthetic preference could be related to the awareness of the affective state induced by aesthetically pleasant stimuli. Although the anterior cingulate cortex is cytologically distinguishable from the posterior cingulate cortex in both humans and monkeys, other conspicuous differences exist. The most obvious of these is the presence of two areas in humans (BA 33 and BA 32’) that are not found in other primates (Amiez, Joseph, & Procyk, 2005; Vogt, Nimchinsky, Vogt, & Hof, 1995).

Additionally, Nimchinsky, Gilissen, Allman, Perl, Erwin and Hof (1999) have shown that the anterior cingulate cortex of great apes and humans contains a type of neurons, known as spindle cells, that have not been found in other mammals, including other primate species. In humans these neurons constitute 5.6% of pyramidal cells of transverse sections of layer Vb, and appear in clusters of between 3 and 6. Among other hominoids, a similar trend is observable in bonobos. Conversely, the relative abundance of these neurons is smaller in common chimpanzees, gorillas and orangutans, and exhibit little or no clustering. These results indicate that a new kind of neuron appeared in the anterior cingulate cortex at an early point in the hominoid lineage. The abundance of these neurons gradually increased throughout evolution, and they began clustering together. Nimchinsky and colleagues (1999) hypothesized that the main function of these neurons is to integrate affective information and transmit it to motor brain regions related with vocalization, facial expression or autonomic functions. Allman, Hakeem and Watson (2002) suggested that the increase in spindle cell proportion could be related to enhancements of emotional stability and self-control. Furthermore, they argued that together with the increase of the anterior frontal cortex, abundant spindle cells played a relevant role in the management of the requirements related to the growth of family size throughout human evolution.

Orbitofrontal Cortex

Kawabata and Zeki (2004) identified greater activity in the orbitofrontal cortex when their participants rated the stimuli as beautiful than when they rated them as ugly. A large number of studies have reported activity in this region when participants were delivered primary and abstract rewards, which suggests that its role in aesthetic preference could be to represent the reward value of visual stimuli.

The comparison of the orbitofrontal cortex of a considerable amount of macaques and humans revealed that the pattern of sulci and convolutions was similar in both species (Chiavaras & Petrides, 2000), though the human patterns were more intricate and variable than the monkey patterns. Despite this conservation in the sulcal pattern of the orbitofrontal cortex, and other general morphological and cytological similarities, which led Semendeferi, Armstrong, Schleicher, Zilles and Van Hoesen (1998) to consider that the state of BA 13 in humans was primitive, certain features of this region distinguish humans from other apes. For instance, in humans and bonobos BA 13 is relatively smaller than in other apes. Together with other aspects, this suggests that the number of orbitofrontal cytoarchitectonic subareas has increased throughout human evolution. Additionally, the cellular density of this area in humans is the lowest among all hominoids and, together with gibbons, they have the lowest grey matter index. This means that, relatively speaking, there is a greater space occupied by axons and dendrites (Semendeferi *et al.*, 1998).

Rolls' (2004) revision of the functions of the orbitofrontal cortex of primates revealed that this region is functionally conserved in humans, in the sense that, as is the case with monkeys, it includes representations of smell, taste, food texture, visual information received from the ventral stream, as well as necessary information for facial recognition. In primates this information is used to identify the stimuli that are being processed and to establish their reward value. Furthermore, both in humans and monkeys the orbitofrontal cortex is a crucial element in learning associations between stimuli and rewards, and modifying them when contingencies vary.

Frontal Pole

Jacobsen and colleagues' (2006) results showed that while participants rated the beauty of geometric visual stimuli, activity in the frontal pole was greater than when they rated the symmetry of the same stimuli. Previous studies have found activity in this brain region during the performance of evaluative judgments of a broad range of visual materials.

Petrides and Pandya (1999) compared the macaque and human BA 10, located in the frontal pole. This study revealed that the architectonic features that distinguish this area from the surrounding ones are the same in both species. This means that the kinds of neurons in this region, as well as their distribution in cortical layers, have varied little throughout the hominoid and human lineages.

Semendeferi, Armstrong, Schleicher, Zilles and Van Hoesen (2001) performed a qualitative and quantitative study of BA 10, comparing data taken from macaque, gibbon, orangutan, gorilla, chimpanzee, bonobo and human brains. Their results confirm that, with the exception of gorillas, BA 10 is easily identified in the frontal pole of all hominoid species. Yet, there are certain traits that distinguish BA in human beings from other hominoids. First, its size is larger, both in relative and absolute terms, Second, although humans exhibit the largest absolute amount of neurons, neural density in this region is the lowest among all hominoids. This affords a greater space for connections with cells from the same and different areas, especially, as observed by Semendeferi *et al.* (2001), other association areas.

Summary

Our review has revealed that some areas shown by neuroimaging studies to be involved in aesthetic preference are relatively conserved in humans, while others exhibit a number of derived features. Occipital visual areas, whose activity during aesthetic preference has been interpreted as the correlate of emotional or attentional engagement, show a mosaic of novel and primitive features. Whereas areas supporting early visual processing seem to be largely conserved, those involved in later stages seem to have undergone modifications to a larger extent. Specifically, the processing of spatial information and the organization of visual information to guide action seems to have been enhanced during human evolution, rather than object-centered visual analyses.

Activity within the temporal pole has been related to the creation of a mnemonic and emotional context for aesthetic preference. Our review has revealed that this region performs very similar functions in monkeys and humans. These functions are essential for the categorization and recognition of familiar objects and the integration of emotion, memory, and sensory information.

The orbitofrontal cortex presumably supports the representation of reward value of visual stimuli during aesthetic judgment tasks. It seems that to a large extent its sulcal pattern, cytoarchitecture, and functions, are conserved in the human brain. The only derived features appear to be an enlargement of area 10 and a reduction in neural density. A similar picture emerges after reviewing the comparative literature on the frontal pole, involved in the decision-making stage of aesthetic preference: A relative enlargement and reduction of the density of neurons. There is also a great cytoarchitectonic similarity between humans and monkeys in the other regions shown to be involved in decisions about the beauty of visual stimuli, the mid-dorsolateral and mid-ventrolateral cortex. In addition to a considerable enlargement during the evolution of our species, the main difference between monkeys and humans is that the dorsolateral regions of the latter seem to receive multisensory information, rather than mainly visual ones. Overall, the complexity of prefrontal cortex connectivity patterns seems to have increased after our lineage split from chimpanzees some 7-8 million years ago. Finally, our review of comparative work on the anterior cingulate cortex, which probably plays a role in the conscious awareness of the affective state during aesthetic preference, has revealed two major modifications in cytoarchitecture: The appearance of two novel cytoarchitectonic areas, and the clustering of a kind of neurons unique to great apes and humans.

Conclusions

The studies we have reviewed in the present work afford a series of considerations we feel should be taken into account by evolutionary approaches to aesthetic preference. First, we have argued that psychological research, summarized and accounted for by two recent models (Chatterjee, 2003; Leder *et al.*, 2004), and neuroimaging experiments suggest, that it is misleading to conceive aesthetic preference as a single cognitive process or mechanism. These studies have shown that aesthetic preference is supported by the performance of multiple cognitive processes, related to perception, recognition, meaning, attention and decision-making, as well as affective processes that interact with the former. Second, an enormous body of literature shows that each of these processes plays an important role in the performance of several other tasks. None of the cognitive or affective processes that psychologists have found to be constituent elements of aesthetic preference seem to be exclusively involved in this capacity, and the same can be said of their neural correlates.

Third, our review of the comparative literature has shown that brain regions whose activity underlies aesthetic preference tasks do not share a common evolutionary pattern. In fact, the functional and cytoarchitectonic organization of some of these regions seem to have undergone little variation since the human and chimpanzee lineages split, whereas others exhibit conspicuous modifications. We believe that evolutionary approaches to aesthetic preference should be able to account for the evolutionary history of the neural correlates of such capacity. Specifically, these approaches should take into account that during the evolution of our lineage the following aspects seem to have varied little: (i) the substrates of early visual processes; (ii) the ventral visual processing stream and its involvement in the recognition and classification of objects; (iii) the cytoarchitectonic organization and connectivity of the temporal pole and its involvement in the generation of an affective and mnemonic context; (iv) the organization of the lateral, orbital and anterior prefrontal cortex, both at an anatomical and functional level. Additionally, evolutionary accounts of aesthetic preference should account for the relation between the appearance of this capacity and the following cerebral changes that occurred throughout human evolution: (i) The development of the dorsal processing stream, related to an enhanced analysis of spatial relations; (ii) the increase in the variety of sensory information reaching and processed by the prefrontal cortex; (iii) the increase in the connectivity among prefrontal cortical regions and between these and other brain regions; (iv) the appearance of novel cytoarchitectonic areas and a new kind of neurons in the anterior cingulate cortex, related to the awareness of one's own affective states.

These considerations suggest that some of the mechanisms that support the human capacity to appreciate beauty, those related to the visual representation of objects, the representation of their reward value and certain executive functions, were already present in our primate ancestors millions of years before the emergence of our species. Our appreciation of beauty, however, also required certain brain modifications that occurred throughout human evolution, presumably related to a greater integration of sensory information, an enrichment of spatial analyses, and an enhancement of the awareness of affective states. Aesthetic preference emerged in human beings, thus, by virtue of a kind of mosaic evolution, resulting from the integration of these derived processes and structures with the pre-existing primitive ones. In contrast to Tooby and Cosmides' (2001) position, we believe that it is not necessary to argue that the changes that afforded human beings the capacity to appreciate beauty were selected precisely for that motive. In fact, given that the brain regions identified by neuroimaging studies, as well as the cognitive and affective processes they support, do not participate exclusively in aesthetic preference, we believe they are the result of multiple selective pressures and that they must have conferred adaptive advantages in diverse spheres of human experience.

This view of the evolution of aesthetic preference, compatible with what is known about the cognitive and affective processes involved in aesthetic preference, their neural correlates and the comparative study of the human brain, is difficult to reconcile with two of the features that characterize approaches framed within narrow evolutionary psychology, as used in Bechtel's (2002) work: The view of aesthetic preference as a separate module or cognitive programme, and the notion that it was selected for in our Pleistocene hunter-gatherer ancestors. As mentioned above, evolutionary psychology in a narrow sense usually considers that aesthetic preference is grounded on a sort of beauty detector, a kind of module or autonomous programme, which performs a specific function to solve a specific adaptive problem. However, as noted by Shapiro and Epstein (1998), evolutionary approaches to human cognition do not necessarily require the adoption of this specific modular conception of the mind. They argued that it is misleading to identify cognitive processes with the tasks or objectives they are used for, as evolutionary psychologists do. Natural selection does not necessarily select different cognitive processes to resolve different adaptive problems. It is much more probable that diverse cognitive processes are involved in the solution of each of the adaptive problems pointed out by evolutionary psychologists, and that each of those processes would be useful to solve various adaptive problems. Bechtel (2002) and Atkinson and Wheeler (2004) argued that neuroscientifically sound modules do not refer to tasks such as cheater detection, mate selection, or the detection of beauty, but to finer grain sized information processing operations. These processes can be involved in a multitude of adaptively relevant tasks. In relation to aesthetic preference, there is currently little doubt among psychologists and neuroscientists that the best way to conceive aesthetic preference is as the result of a varied set of processes, from those related to the perception of the most basic features to those underlying deliberation and decision making.

Finally, it is usually considered that in order to explain the origin and evolution of human cognitive processes it is sufficient to understand the problems faced by our Pleistocene hunter-gatherer ancestors (Tooby & Cosmides, 1992). This assumption faces at least two main problems. First, during the Pleistocene period our ancestors lived in a variety of environments, not merely savannas (Foley, 1995). In fact, the Pleistocene period saw the expansion of humans in many parts of the world, from the African plains to the woodlands of Southeast Asia and the sub-glacial valleys of northern Asia and Europe. It is difficult to see that these environments share a stable common set of selective pressures, and that these were not present, say for instance, in the environments of our Pliocene ancestors. Furthermore, the view that the origin of human cognition is to be found in Pleistocene savannas ignores that rarely in evolution do completely novel systems or mechanisms appear. This is the essence of Darwin’s (1859/1991) notion of descent with modification. Just as the origin of bipedalism and human erect posture cannot be understood without reference to previous forms of locomotion and skeletal designs, human mental and neural mechanisms did not appear in a vacuum. They are surely the result of modifications to mechanisms inherited from our ancestors, including Pliocene hominids, and even earlier primates. In the words of Bechtel (2002):

> “[…] evolution begins with existing complex entities and modifies them. This is very different than a picture of developing new modules de novo. Moreover, it imposes an important constraint on evolutionary models – that they be grounded on information about phylogeny and the ancestral condition before the acquisition of a new ability” (Bechtel, 2002; p. 223).

There is no question that Pleistocene environments exerted strong selective pressures on our ancestors in relation to the appreciation of beauty, among many other cognitive and physical traits. The literature provides evidence of changes in cognitive and neural systems throughout this period of human evolution. But the fact is, that these pressures were acting on brain structures and processes that had been inherited from earlier ancestors. Our review of the literature has shown that part of the cognitive and neural underpinnings of aesthetic preference were already in place millions of years ago in our primate ancestors, which we share with some current primate species. Hence, evolutionary approaches to aesthetic preference cannot limit the study of the selective pressures and environments to those affecting our savanna dwelling hunter-gatherer ancestors. We believe that knowledge of the selective pressures acting on early hominids, hominoids, and maybe even earlier primates, as well as their cognitive adaptations, will provide a rich and necessary complement to understanding the evolution of aesthetic preference.

Acknowledgements

This research was made possible by a research grant HUM2007-64086/FISO awarded by the *Dirección General de Investigación del Ministerio de Educación y Ciencia*.

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CHAPTER THREE

IN SEARCH OF INNER WORLDS: ARE HUMANS ALONE IN THE MENTAL WORLD OF POSSIBLE FUTURES?

MATHIAS OSVATH

Abstract: The experience of an inner mental world constitutes much of what it feels like to be human. The inner world is an astounding result of biological evolution. It is not unlikely that other species than Homo sapiens would benefit equally from possessing an inner world. Nevertheless, this possibility has been more or less neglected in scientific studies seemingly due to philosophical ideas stemming from Descartes. One way to approach the question of the existence of inner worlds in animals is by investigating their abilities to travel mentally in time, as such recollection and planning abilities strongly imply an experienced inner world. We have conducted a series of experiments on chimpanzees and orangutans that robustly suggest the ability to travel mentally forward in time, to plan for future states. These findings considerably raise the probability that humans have company in the inner world.

Introduction

Humans are very much inner world dwellers, often just roaming but also navigating it with great accuracy and purposefulness. The world of humans does not disappear when the eyes are shut. Instead we experience life-like episodes from the past, things to come or scenarios that will never even occur. The inner world is an extraordinary place where just about anything can happen with only modest deliberate effort from the inhabitant. On some occasions we have limited control over what takes place in front of our mental senses, for example, when we dream in our sleep. As a matter of fact, the inner world nearly constantly accompanies us. We even suffer from great difficulties of evading it – the number of preachings on how to seize the moment is a telltale sign of this odd human disability. Actually, neurological data reveals that when our brain is at wakeful rest it cannot help but make us ponder on the future or the past, or to produce inner speech or simulate behaviors (Christoff et al, 2004; Andreasen et al, 1995; Ingvar, 1979).

The life-like mental world with its first person perspective attracts much philosophical attention, as it constitutes fundamental aspects of a self-consciousness. This inner world concept is a source of disputes, and raises intriguing and nearly insoluble questions about ontology and phenomenology. What is the nature of this world? Who is the one experiencing it and where does that one reside? What does it actually mean that it is “like being” a perceiver of the mental episodes? And so on.

However, such questions are not the topic of the upcoming text. Here the premises are put rather plainly: There exist cognitive processes that, in an every day sense, are interpreted as an inner world by us, and such processes probably have a biological fitness value, and should hence be viewed as evolved cognitive mechanisms. The overarching question asked is instead if the human animal is the only one who has evolved such a world? Empirical data from studies on prospective cognition in great apes will form the core of the answer. But first a possible evolutionary context for a mental world will be outlined. It will be followed by a brief discussion about some common views and ideas on the possibility of experienced inner worlds in animals – views that might create obstacles for the scientific study of animal cognition.

Evolving an Inner World

Many of us would argue that acting in our inner world is more or less synonymous with thinking. Manipulating the inner world is seemingly what we do when we think. We mentally design various things and scenarios that we at times transfer to the physical world we share with others. Despite the intuitiveness of this folk psychological concept, it does not hold for a closer look. Most of our cognition is as anonymous as the blood flow or the pumping in our cells (it is not until it fails to function that we might indirectly become aware of the processes). We are certainly not conscious of the bulk of our own cognition. The illusion of the inner world as the main stuffing of our heads is due to the inwardly directed beam of awareness that only seems to capture this inner world and not very much else (perhaps this “beam” even *is* the inner world).

So, in the dawn of cognition, lifelike inner worlds probably did not exist. Though the animal kingdom was devoid of this mental environment, many species soon started to carry cognitive models of different ecologically important aspects of the outer environment. Such models could be described as cognitive simulators or emulators (Gärdenfors, 1995; Grush, 1997; Hesslow, 2002). To put it simply, this kind of mental models test actions before the organism executes them. The simulators considerably improve the swiftness of actions, as the nervous system is relieved from the constant adjustments to the environmental feedback in order to inhibit or exhibit the signals governing the muscular tensions. An action, including the environmental feedback, is instead simulated within the organism before it is initiated and thus, a pre-fabricated action can be utilized at once. The fidelity of these simulators differs and depends on training and development in ontogeny and on phyologenetical requirements. Most animals entrust their lives to simulators though. If a chimpanzee or a squirrel does not accurately enough simulate the jump to the next branch, the consequences might be fatal. Trial and error does not suffice in a long range of ecological niches. When an animal develops a simulating system of some sort it can occupy a niche which otherwise would be blocked. Karl Popper, with famous elegance, illustrates the utility of the internal models by expressing it as they let our hypothesis die in our place.

Primordial simulators were only connected to immediate actions with a minimum of delay between incoming stimuli, the simulation and the execution of an action. Further on, simulators could, so to speak, run off-line (Grush 1997) and handle more complicated action possibilities (as in case of the jumping ape or squirrel). Later in evolution, or perhaps simultaneously, cross-modal simulators would have had notable fitness value, as they allow the coordination of the simulators of the different senses in an action, for example, eye-limb coordination.

It is not necessary for the owner of such cognitive simulators to be aware of them in order for them to work. Some are probably more or less innate and others must be filled with information from the environment, for example, during childhood. The environment in which they are used must have high degrees of regularity in the aspects relevant for the different simulators, otherwise it will not be possible to fill the simulators with generalizable information, either phylogenetically or ontogenetically.

In niches with less regularity due to more complex causal relationships or an often changing environment, or when novel solutions increase fitness, another simulating system is needed – a system that is not only dependent on the faithful replication of the well-established information stored in the simulators. Such a multifarious environment might, for example, be a social one, where the behaviors of other cognitively advanced creatures must be taken into account before acting. The need for simulating something novel or to foresee different possible infrequent or complex scenarios seems to have been met by the evolution of an experienced inner world. An experienced inner world gives the owner the great benefit of being able to compare and relate different experiences to each other. It is possible to compare a currently experienced state in the physical world to a possible future, one that is simulated in the inner world. Or, different inner world experiences could be compared to each other. On the basis on these experiences the individual can make choices and form decisions. This system could, in other words, be a provider of different emotional information to be used in a decision process. That is one important reason why the inner world is actually experienced, as experiences yield emotions. It should also be added that a mental life-like inner world are almost necessarily experienced, because it would clearly not be of much utility to construct such an environment in an organism that is blind to it. This argument must not be confused with sophism, rather it states that if a life-like inner world really exists, it is experienced by the owner – the *existence* of this world is yet another question.

Pessimistic Views on the Possibility of Non-Human Inner Worlds

There is a widespread tendency among empirically oriented scientists and philosophers to avoid serious considerations of the possibility of experienced inner worlds in non-humans. Such awareness is readily and seemingly by default excluded from most interpretations of experimental results or observational data from non-humans. Instead, great effort is put into formulating explanations lacking such awareness – resulting in filling animal heads with elaborate learning mechanisms from one end and draining off any experienced inner worlds from the other.

Part of the explanation for this reluctance is the so-called Morgan's canon, which has turned into the golden rule that any respected comparative psychologist must cherish and practice by. The canon was formulated by the pioneering comparative psychologist Lloyd Morgan (1894) and spells: "In no case may we interpret an action as the outcome of the exercise of a higher psychical faculty, if it can be interpreted as the outcome of the exercise of one which stands lower in the psychological scale". Strangely enough, this is an obvious expression of a belief in a *scalae nature,* which comparative psychologists on the other hand are taught to shun, as such a scale is incompatible with the idea of evolution. There can be no "higher" or "lower" in the teleological sense in the future blind process of evolution. For some reason the canon is regarded as a version of the principle of parsimony. This was clearly not Morgan's intention, who even defended the lack of parsimony in the canon. He expressed that a leaner explanation is not necessarily the correct one. The implicit and peculiar conclusion drawn by later researchers is that Morgan actually misunderstood what he himself meant – the canon is indeed about scientific parsimony (Radner & Radner, 1989).

Nevertheless, Morgan, misconstrued or not, is not to blame for the underlying assumption that awareness of the inner world is "higher" or more complex than many of the cognitive processes that substitute this awareness in the explanations of non-human behaviours. Rather, Descartes is usually held accountable for digging this trench between humans and the rest of the tens of thousands of species possessing a nervous system. Without much controlled empirical data and with a great deal of introspection, Descartes assumed that humans alone have an aware experience, and that animals are more or less complicated automats. The Cartesian view on the matter has had a substantial impact and has survived for almost four centuries in Western thinking. Despite that, this fact in itself is rather awkward, given the amount of research carried out since then, there are also other peculiar implications hidden in this approach. Cartesian adherents explicitly agree that this awareness is uniquely human, but what is less obvious is that this for them also implies that the ability is higher than non-aware abilities that could perhaps explain the same behavioral results. Simply because the ability is allegedly human, it appears – human equals cognitive height, and lower means non-human. Hence, and in purported accordance to Morgan's canon, the behavioral data from non-humans are interpreted in lower terms, that is, excluding an inner awareness. The consequences of this belief approaches circularity. Frequently used escape routes in explaining animal cognition are elaborate models of associative learning (Griffin & Speck, 2004; Byrne & Bates, 2006; Call, 2006). Theories of conditioned learning mechanisms undoubtedly have great merits in their explanatory and predictive powers in an array of circumstances, and often they do indeed offer the most parsimonious approach. However, when accounting for behaviours of animals that when displayed by humans clearly rely on other mechanisms than associative learning, for example, problem solving in novel situations, then associationistic explanations tend to become extremely convoluted. The associative learning models lose most of their predictive strength in such cases; they rather become *post hoc*, bringing the models close to *ad hoc*. In other words, it does not seem possible to foresee some animal behaviours by applying associationistic accounts; it is only after the exhibition of a certain behavior that it is possible to come up with an explanation of associative learning.

Serious scientific endeavours to explore animal cognition must be cleared from ancient ideological debris, without discarding the principle of parsimony or picking up new heavy ideological baggage. Evolutionary theory should be an appropriate starting block. For example, the hypothesis that complex traits have common origin if shared by species in phylogenetic proximity, could most reasonably serve as the null hypothesis also when it comes to comparing human cognition to that of others. Most comparative psychologists would agree upon this, the problem is rather what criteria should be used to be able to say that the “same” cognitive traits are exhibited in two or more different species. Such disagreements do, however, not diminish the validity of the point I am trying to advocate: An experienced inner world would doubtlessly carry a biological fitness value for individuals from a range of species. This special cognitive simulation of an environment must be treated as an evolved biological trait and not as something outside the realm of nature and only by definition unique to humans.

Empirical Studies

There are different ways to probe the question about the existence of an inner world. In language competent creatures like humans one could listen to what is expressed and quite soon figure out whether there seem to be an inner world within the speaker, or we could of course just ask. When such communicative abilities are lacking or when we have problems interpreting them, one must rely on other behavioral criteria than language expressions. One of these has received much attention in recent years and is the display of the ability to travel mentally in time.

Mental time travel is closely related to the concept of episodic memories, coined by Tulving (1972**)**. Episodic memories enable recollection of specific events as opposed to just knowledge about something. Tulving illustrates this by pointing out the difference between knowing the rules of chess and remembering ever having taking part in a chess game. This recall is the backward mental time travel. The forward part, projecting into possible futures, is believed to rely on the same cognitive system as episodic memories do (e.g. Atance & O’Neill 2001, 2005; Suddendorf & Busby 2005; Suddendorf & Corballis 1997, 2007; Tulving 2005). There is a growing wealth of neurological data to support that, in humans, the same brain structures are used when engaging in tasks that involves either episodic memories, planning or even the use of a theory of mind (for review see Buckner & Carroll 2007). The defining character of mental time travel is the experience of a first person view in the inner world. Accordingly, such travels involve, as mentioned above, a certain form of self-consciousness, called autonoetic in this context (e.g. Tulving 2005, Gardiner 2002).

The ability to plan for future drive states or to travel forward in mental time seems to be the greatest evolutionary gain with an inner world or an episodic system, as it gives a high flexibility to the individual that can regulate actions far in advance in an optimal way. As discussed, the inner world is assumed to be a human unicum, and the assertion of human exclusiveness in future-oriented cognition specifically is dubbed the Bischof-Köhler-hypothesis (Suddendorf & Corballis, 1997). It spells that non-humans cannot differentiate future states from current ones. This means that they are unable to plan for something that is different from their current drive state. Many animals are seemingly proficient planners when it comes to immediate drives, for example, if they are hungry they figure out sequences of different actions in a specific order to get to food. However, they are supposed to lack the ability to plan for a state that they are currently not experiencing. Such planning is not to be confused with behaviours governed by innate releasing mechanisms, like migration, hibernation or hoarding. The assumed animal disability does not, however, imply that humans should be able to plan without any mental reference to the future in the current situation. Rather, it does mean that animals lack the ability in one way or another to suppress a predominant current drive state in favour of a future one – to give priority to an imagined state before the currently experienced one. As mentioned above, this would be much of the point of experiencing an inner world in a fashion similar to the real world. Two experiences can be weighted together and compared. If it were shown that non-humans engage in mental time travel, and perhaps in planning specifically, then it would constitute firm evidence that humans are not alone in the world within.

The most extensive and cohesive research program on mental time travel in animals has been conducted on scrub-jays by a team in Cambridge (e.g. Clayton & Dickinson 1998, 1999; Correia et al 2007; Raby et al 2007). These corvid birds exhibit impressive behaviours related to caching, suggesting not only that they have episodic memories, but also that they plan for future drive states and even have a well developed intersubjectivity. These abilities appear to be analogous to the ones managed by a given core brain structure in humans, which is interesting considering the differences between avian and mammalian brains. Despite the fact that these experimental data appear convincing in establishing mental time travel in non-humans, there are several who do not find them conclusive. Mainly because it is argued that associative learning or innate mechanisms are not sufficiently excluded (Gilbert & Wilson 2007; Premack 2007; Suddendorf & Corballis 2007; Tulving 2005; Roberts 2002, 2006). There have also been studies on great ape ability to remember episodically or to use prospective cognition (Schwartz et al 2005; Mulcahy & Call 2006). However, they have received even more severe critique than the corvid-studies for not eliminating the possibilities of associative learning, and for lacking controls for the animal's mental state in the testing situation (Suddendorf & Corballis, 2007; Tulving 2005; Roberts 2002, 2006).

As it seems, the proponents for the existence of mental time travel in non-humans are gaining ground, however the case is still not settled.

Great Apes Use Self-Control and Envisioning in the Face of Future States

In a series of four experiments we wanted to find out whether great apes are able to out compete strong current drive states in favour of highly delayed future rewards, and if they use processes that could be described as envisioning when acting towards the future (Osvath & Osvath, 2008). It is essential to answer these questions as such abilities form the basis of true future planning and forward mental time travel, and hence are signs of a complex inner world of possible futures. It has not been shown before this study that great apes are able to compete with their immediate drives while taking actions for the future. The only previous study on great ape prospective cognition (Mulcahy & Call, 2006) did not control for the drive states. It has been argued that the subjects in that study might have been governed by the same drive, craving for grapes, throughout the experiment, and that their key behaviours were not an expression of actions made towards a deviating mental state in the future (Suddendorf 2006, Suddendorf & Corballis 2007). Equally important to measuring drive states is the exclusion of associative learning as an explanation of the results. Associatively learned behaviours are, as described above, often viewed as the opposite of behaviours originating from a conscious process; hence it must be convincingly shown that great apes are not influenced by such learning in the experiment. The Mulcahy and Call study was also criticized for not excluding this possibility. The main argument was that the same tool was rewarding throughout the experiment, and thereby it is not impossible that the relationship between the tool and the reward was purely associatively learned (Suddendorf & Corballis, 2007).

We engaged two female chimpanzees (*Pan troglodytes*) and one male orangutan (*Pongo abelii*) in our study. Before the experiments started, the subject received brief training in using a thin plastic hose as a straw to obtain a large reward of sweet and satiating fruit syrup from an apparatus. A keeper demonstrated the function of the tool by using it in front of the subject and then handing it over. All three subjects immediately and spontaneously reinserted the hose and used it appropriately by sucking up the sweet liquid. This was the only occasion during the whole experiment series where there was only a short delay between obtaining the tool and accessing the apparatus. Then the subjects were shown a tray containing four objects out of which one, the hose, was functional for acquiring the reward. The other three objects were previously used in different enrichment activities in the daily lives of the apes, and thus probably familiar. The subject was only permitted to select one of the items. Prior to this, a bias control was conducted on three apparatus naïve apes not participating in the study – there were no significant biases found in the selection of the objects. The selection was made when the apparatus was visible but unattainable in the reward room. Subjects were not allowed into the reward room until one hour had passed after their selection. All subjects selected the functional tool in the first training trial. After this training session, the apes were exposed to the reoccurring nature of the reward in order to create possible incentives for possessing a functional tool for the future. This was done by granting subjects without tools access to the reward room containing the baited apparatus. This frustrating procedure was repeated twice daily.

The baseline experiment. The following day the actual testing began and the apes were respectively called into a selection room. From this room it was not possible to see the reward room. When inside, the subject was offered a choice of the kind described above: Among three enrichment objects and the functional hose. After their selection they were let out to their everyday enclosure shared with the rest of their social group. Then a 70-minute delay followed until the baited apparatus was installed in the reward room and the subjects were granted access. In other words, to obtain the reward the ape had to select the functional tool in a location with no visual cuing to the reward site, save and protect the tool for more than an hour in a social environment and then use it when let into the reward room. All three subjects performed significantly above chance. Out of the 14 trials conducted on each subject, one orangutan and one chimpanzee selected the functional tool in 100 % of their choices, and the other chimpanzee selected it in 13 trials. The subjects obtained the reward in approximately 80 % of the trials when they had selected the appropriate tool. The tool losses in the chimpanzee trials were most often caused by a playing infant that misplaced the hose. The orangutan actually brought the tool in two (of three) cases that were recorded as losses, however, in a non-functional state due to being carried in the mouth (in relation to the teeth of a male orangutan the tool was quite fragile). The results of this first experiment constructed a baseline for further experiments in the series. And, perhaps more importantly, it did not only confirm the results from the previous prospection study on great apes (Mulcahy & Call, 2006), but it also showed that apes are able to take actions towards the future in a location that has not been associated with the forthcoming event. Furthermore, this experiment shows that the apes in a prospection task can cope with the cognitive load added by sharing their waiting time with the rest of their social group.

The self-control experiment. The first experiment did not control for competing drives when the subjects carried out the key behaviour. This control was addressed in the second experiment, where it was tested whether subjects could suppress the selection of an immediate reward in favour of the tool needed to obtain the larger future reward. The inhibitory ability investigated in this experiment is often described as self-control – the ability to select a delayed larger reward instead of an immediate smaller one (e.g. Tobin & Logue 1994). Self-control in humans is allegedly unparalleled by any other species. The purported impulsivity of non-human animals is taken as evidence for the hypothesis that they are mentally stuck in the present moment (Köhler, 1921; Roberts, 2002, 2006). The ability of self-control has been widely studied in a range of different research paradigms from psychiatry and psychology to animal cognition and economics. Self-control appears to be a demanding ability that develops late in ontogeny and is profoundly integrated in human cognition. The levels of self-control in humans predict the individual success in domains as different as interpersonal skills, academic achievement and psychopathology (Mischel et al 1989; Tangney et al 2004; Carlson & Moses 2001; Duckworth & Seligman 2005).

While human self-control might span over long delays, minutes and hours or even months and years, the ability of most of the tested animals appears restricted to seconds. Interestingly, it has predominantly been pigeons and white rats that have represented the non-human animals. Therefore it is not surprising that recent self-control studies on great apes, which are as closely related to pigeons and rats as we are, show impressive results (Beran et al, 1999; Beran & Evans, 2006; Evans & Beran, 2007;

Rosati et al, 2007). Some results even indicate that chimpanzees in some contexts are more competent than humans in self-control tasks involving food rewards (Rosati et al, 2007). This makes great apes good candidates for being fellow inner world dwellers. Self-control is likely the most potent experimental control for the drive states in a planning context. The impulse to experience immediate satisfaction must be fought in favour of making the future slightly brighter than the present.

In this experiment all relevant aspects of the set-up in the previous experiment were kept, with one crucial exception: A much-favoured fruit, a grape, was added to the selectable items. If animals are unable to differentiate future states from current ones, they are expected to select the immediate reward. Out of the 14 trials conducted on each subject, one chimpanzee selected the functional tool 8 times, the other chimpanzee chose the tool 11 times and the orangutan selected it 9 times. The rest of the choices were the grape. These results are significant. The level of performance is comparable to that of humans (Forzano et al, 1992), which confirms the results of Rosati et al (2007). To date, these results actually show the highest level of self-control demonstrated in non-human animals.

The association control experiment. If unable to anticipate a future reward, it would be irrational to select something that is useful in the future instead of something that is immediately rewarding – there would not be an obvious beneficial point such behaviour. However, if the selection was not due to intentional cognition, but associative learning then it would not have required prospection. The tool would be selected more often than the fruit only because it would be loaded with a high reinforced value. More than a century of research in conditioned learning has not revealed any processes that could credibly explain the impressive levels of inhibition described above. Even so, it is worthwhile to control for any not yet discovered associative learning mechanism, as such mechanisms are readily and creatively suggested by proponents of non-cognitive explanations of animal behaviour.

The third of our experiments controlled for such associations. If there was an associatively learned link between the tool and the reward, then the tool would only carry an intrinsic value. Its value would not be cognitively related to its future function in the mind of the ape, it would rather be a reinforced arbitrary connection stored in the associative system of the animal. The results of the self-control experiment would then be an expression of the strength of this associative link and not of self-control at all. In other words, the animal would in fact have faced two immediate rewards, where the plastic hose in itself constituted a higher reward than the grape. To investigate this possibility we let the subject select between objects identical to those of the baseline experiment. When the subject had selected the hose as expected (from the results of the first experiment) and thus had it in its immediate possession, it was instantly offered a new choice, including a grape, making this set-up identical to the one in the second experiment. If the functional tool only carries its value in itself, the second selection should mirror the results in the self-control experiment. If, however, the tool had its value related to its future function, then the grapes would be the expected choice in the second pairing.

In the 14 trials conducted on each ape, no one selected a second functional tool when already possessing one, but maximized the rewards by selecting a grape. It is worth pointing out that this does not necessarily mean that the tool did not evoke positive associations in the apes, it probably did just as precious tools might evoke positive feeling in humans, rather the results show that the value of the tool is not associatively *learned*.

The envisioning experiment. It might be intuitively hard to understand the complex cognition about future states revealed in the described experiments without assuming that the apes actually envision those states. Nevertheless, this is a theoretical possibility and thus, more insights are needed into which processes are used when the ape is selecting with the future in mind. One way to control for whether a possible future event is simulated by envisioning, is through measuring the ability mentally to include a novel object in a possible future scenario. To face an object that has never before been encountered and then, based on its functional properties that are only inferred, integrate it in a plan would be a feat implying envisioning. Such complex simulations of the states in the environment are prime examples of what an inner world would be suitable for.

From this assumption we conducted the fourth and last experiment in this series. This time the apes were exposed to novel tools that were highly dissimilar to the original functional tool used in previous experiments. Two of the other selectable objects were also exchanged for novel objects. These were included on two grounds, one was their attention grabbing effect on humans and the other that one of them should bear some similar features to the functional hose but obviously not its function. The fourth object included in all the trials was the familiar bamboo stick, associated with honey extraction in enrichment activities. It could also be used to extract the fruit soup in a highly inefficient way (similar to eating soup with a fork). The functional tools were either pipes or hoses of different lengths (between 40 and 58 cm), materials (plastic, rubber, wood, metal, fabric), shapes (round, square and triangular) and colours (white, black, orange, beige, grey, multicolour, metal and wood) (see figure 1). Twelve trials with unique objects were conducted on each subject. Prior to these trials a bias control was conducted with the three naïve apes that took part in the control in the baseline experiment. In this control no functional object was selected significantly above chance. However, the three control subjects in three trials chose the same distracter.

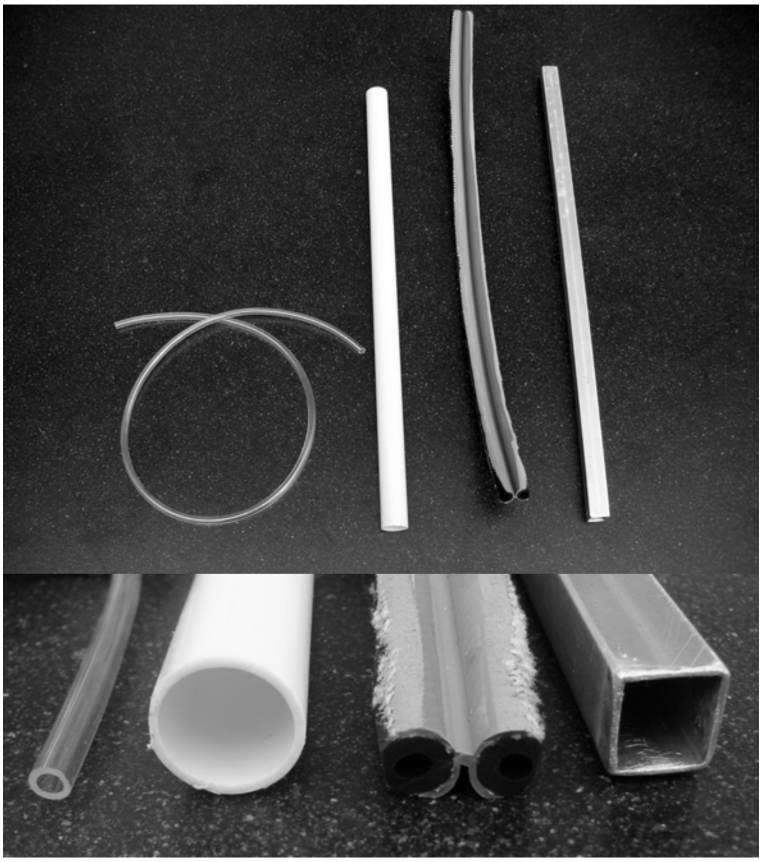

Figure 1: A comparison between the functional tools used in the study. The hose to the left was used in the first three experiments, and the other three constituted the novel and unfamiliar tools in the envisioning experiment (the plastic pipe was presented in the first trial, and the aluminum frame in the last). In the picture above their different appearance on the selection tray is shown, and in the in the picture below the different openings are compared.

Each object was rotated in front of the subject by an experimenter in a strict and controlled fashion in two directions with equal amount of time for each direction and object. The functional tool was never demonstrated in first or last position to avoid potential biases. To preclude gaze cuing the experimenter never looked directly at the objects or at the ape but at a point above and beyond the head of the subject (it should be added that this procedure was also applied in the other experiments).

This envisioning experiment differed from the rest in another important aspect. The chimpanzee participants were not sharing the waiting area with each other (though with the rest of the non-participating group), to avoid potential social learning.

The orangutan selected the functional object in 11 out of the 12 trials. One of the chimpanzees, Linda, chose the functional object in 10 trials, whereas the other chimpanzee succeeded in obtaining the correct tool in 9 trials. These results are significant. It is interesting to note that in the successful trials, the apes used the tool on the apparatus with no observable hesitation, even though some of the tools required a different body posture from the one in the previous experiments. Furthermore, when the subjects failed to select the appropriate tool, they did not try to use the non-functional one on the apparatus.

This series of experiments strongly suggests that great apes can use prospective cognition to act towards future events that are not currently experienced. And, the results were verified in another pilot study we conducted on another aspect of planning for the future.

The Other Side of the Coin – When Currently Satiated by the Reoccurring Reward

Competition with drive states can be performed in many ways. Self-control is perhaps one of the most potent examples of this ability. In particularly because it is fairly easy to control this process experimentally. However, it seems to be of equal ecological importance to be able to cope with the other side of the coin – to act towards the future when currently experiencing what could be thought of as a negative need. In other words, to suppress or disregard the current satisfaction to an extent that makes it possible yet again to be satisfied when the drive state reoccurs. Examples of cognitively overcoming physiological homeostasis in order to repeat the state of equilibrium could be filling up a water bottle when quenched, cooking or shopping for food when thoroughly satiated or preparing a night's rest in the morning.

In a pilot study we tested this ability on the male orangutan that participated in the previously described experiments. This experiment was based on tool behavior in relation to a large food reward. The question to be answered was whether or not the orangutan would save the tool leading to the large reward immediately after the consumption of it. The first step in this experiment was to get an approximation and hence a control of when satiation was reached by the subject when offered this kind of reward. The food reward in this experiment was of the same kind as in the previous one: A thick and sweet fruit soup (rose hip berry soup). To a human, this soup is highly satiating due to its syrupy and sweet character. It has a high energy content with about 60 kcal per deciliter. To control for satiation, the orangutan was offered to drink from a bottle filled with 1.5 liters of soup. The subject was given this bottle of drink on three different occasions months apart. Two keepers with more than 30 years of experience of working with great apes, independently of each other made a judgment, based on the behaviour of the ape, when it started to become satiated. They agreed that drinking pace and general eagerness seemed to fade after about 1 litre was consumed. Based on these observations the reward size was set to 1 litre in the experiment.

In the experiment a paper box containing the reward was placed outside one of the two interconnected enclosure, in a counterbalanced fashion, three times a day with pseudo-randomized time intervals between. A thick and rather stiff rubber hose was the only tool that could be used to obtain the reward. If other tools were used, like sticks, then either the paper apparatus would break or the acquired amount of the reward would be extremely limited.

No training on the tool or on the apparatus were given before the experiment. The orangutan was not informed about the reoccurring nature of the reward prior to the experiment. The experiment started with the tool being planted within one of the two interconnected enclosures from where the subject was currently barred. The subject could not see the tool being planted. Then the ape was let into the enclosure and it was recorded when the tool was found. In this first trial it took 5 minutes before the tool was discovered. When 1 hour and 30 minutes had past, the subject was let into the other enclosure outside where the baited apparatus was installed. The orangutan had by now shredded the tool into tiny pieces and therefore could not obtain the reward. He tried using sticks and cloths, though with meagre results. This reward reoccurred three times during the day in and outside the different enclosures with time intervals no less than one hour and no more than three.

The next day the tool planting procedure was repeated. This time it took three minutes before the orangutan found it. After this followed an impressive sequence of three whole days when the orangutan kept track of and brought the tool with him when moving between the enclosures and going to rest at night. During these three days the orangutan successfully obtained the reward three times per day. And the key behaviour, saving the tool by bringing it with him after finishing up the reward, was recorded 10 times. The experiment had to be aborted after three days because of health considerations relating to the extremely high energy and sugar content in the reward.

Figure 2: The male orangutan Naong, who participated in both of the planning studies. Currently he is negotiating the problem of getting the honey trapped inside the small holes drilled into the log.

A control was also conducted by planting a non-functional tool following the same set-up as in the previous experiment. A blue plastic string with the same length as the hose was planted. The subject found it after 1 minute. It was not destroyed, but it was not saved either or brought to the next enclosure. The reward reoccurred three times daily, but the orangutan ignored the string as a tool (and instead returned to using sticks) and did not exhibit any saving behavior related to it. Again, this confirms that tools are saved in accordance to their future function.

This pilot study indicates that apes are able to act towards a reoccurring opportunity to satiate a drive that is currently satiated. Firmer results on this ability would be achieved if the trials were extended with the same subject, as well as including other individuals. Furthermore, it should be noted that it probably does not require much effort for the ape to save the tool – this fact could be modified to reach further understanding in the planning skills of great apes. Nevertheless, these findings give additional verification to the hypothesis that great apes are able to plan for future states.

Discussion

The results from these planning studies on great apes are convincing evidence for the skill for planning for a currently non-experienced state. In humans, such tasks are solved by consulting the inner world, and comparing experiences from the first person perspective. The results are not readily explained by associative learning mechanisms. An associative account would require new, *post hoc* and unverified associative models. When humans display such abilities, it is viewed as a result of mental time travel, planning for the future and the possession of an inner perspective. Human children who solve far less complex tasks than the apes in these studies are viewed as mental time travelers (Atance & O’Neill 2005; Suddendorf & Busby 2005). Great apes are closely related to us and when they exhibit the same traits it should, according to the evolutionary null hypothesis, be regarded as an expression of the same trait derived from the latest common ancestor.

Interestingly, recent neurological data also confirms the results of these studies. It shows that chimpanzees share the high neural activity with humans at wake rest, which is well correlated with the experienced inner world (Rilling et al, 2007). It is indicated that some of the regions recruited to a greater extent in the chimpanzee brain than in the ones of the human subjects are related to emotional processing. This fits the idea of the experienced inner world as primarily a model for emotional information, which constitutes the reason for it to be experienced.

Experienced inner worlds might have evolved in other lineages than that of the great apes. As suggested by the studies on the scrub-jay abilities in mental time travel, it might be that corvids carry avian versions of inner worlds. Perhaps dolphins, or dogs and cats have their own worlds. If other inner worlds exist, naturally they should be species-specific, including the modal and other aspects important in the physical world of the animal. The common ground is that it is experienced from a first person perspective. The simple reason for this is because that kind of experienced simulator would have a high fitness value in some environments.

Obviously, there is the problem of the, in a philosophical sense, impossibility of knowing anything about the phenomenology of other’s experiences. However, that is not really the issue here. The question is not about what it is like to experience something like an ape. I would know just as little about what it is like experiencing something being you (I presume the reader is human). The point is, that the phenomenon of experiencing an inner world is a biologically derived one, and should be viewed as a cognitive mechanism. “What it is like” is a superfluous question in such a context. It is, for example, possible to study biological locomotion, including its motor cognition, without asking what it is like habitually to walk on two legs if you are a human, or on four if you are a cat, or to swim with fins if you are a dolphin.

The problem of the phenomenology in others is intimately related to the problem of solipsism. If nobody else exists with a phenomenology like your own, then others would be rather like rational automats, and then you would be alone. Most scientists and philosophers seem to agree that solipsism is a fruitless view of the world. It is just more comfortable and less dull to assume that there are others out there with minds like your own, sharing roughly the same reality. Having agreed upon that, we use behavioral cues in one of our favorite sports: To figure out what is inside the world of our fellow humans. Perhaps it is time to include more players in the sport?

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CHAPTER FOUR

OBJECT FUNCTION AS A BASIC REQUIREMENT FOR LANGUAGE USE AND TOOL USE

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Abstract: Human beings excel in several domains in comparison to other species. Considering the domains of language use and tool use, human beings appear to be far superior even to our closest relatives. In this paper we shall attempt to argue that the ability to extract and understand the functional characteristics of physical objects may be a central skill that is manifest in human beings, and a skill that serves as a basic prerequisite in order to use language and tools at a substantially more advanced level than is the case for other living creatures.

Object Function as a Basic Requirement for Language Use and Tool Use[1]

What are the uniquely human features or characteristics that make human beings stand out in comparison to other living creatures? Although a range of domains beyond any doubt deserves attention when considering this question, two features, however, appear to be especially prominent: *Language use* and *tool use*.

Language, in a broad sense, is a truly magnificent achievement. Language makes communication in the present moment substantially more sophisticated, elaborated and with more nuances than non-verbal communication. Furthermore, language allows us to move beyond the present by providing the means to communicate about the past, the future, distant locations, persons, objects, issues and events that do not have to be present – or even exist (e.g., Nelson, 1996; Spelke, 2003). Language also provides the concepts by which we order the world into manageable and

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[1] This paper was supported by two grants from the Danish Research Council for the Humanities (No. 273-05-0182; and No. 273-07-0009) to the second author.

conventionalized units. Concept formation is not only a cognitive economical tool for the specific individual (Rosch, 1978); it also serves as the common and shared ground that makes true social communication possible (Mandler, 2004). If someone should attempt to list the most prominent candidates for the characteristics that set human beings apart from other species, even non-linguists would have difficulties not to include language on the list.

We believe that tool use is another central feature by which human beings excel. Tool use may not stand out to the same degree as language use, since other species to some extent also use tools. However, as we shall attempt to argue that tool use in human beings differs from tool use in other species in both quality and quantity. Contrary to other creatures of the earth, human beings *produce* tools, not only to ourselves but also and mainly to distant, potential users whom we do not know and are unlikely to ever encounter.

In this paper we shall attempt to argue that the ability to understand and extract the *functional characteristics* (e.g., Nelson, 1974) of objects may serve the purpose of being a basic requirement or prerequisite in order to excel subsequently in the two above-mentioned and apparently somewhat distant characteristics, namely language use and tool use.

The paper is structured as follows: In the first two sections we will briefly unfold how language use and tool use are truly special in human beings as opposed to other species. We do not claim to present proper reviews of the issues at stake, merely to provide sufficient evidence to substantiate the claim that human beings do indeed excel in these two areas. Given the fact that language seems more complicated and relates to a range of adjacent issues we have devoted more space to language than to tool use. Note further, that when referring to ‘other species’ we have taken the liberty to refer predominantly to the great apes. The third section offers a closer look at how infants and small children learn to extract the functional characteristics of objects. This area is closely related to the development of concept formation and has recently gained considerable renewed interest among researchers in the field after having been almost neglected for two decades. In the fourth section we will for the sake of comparison briefly attend to the role of functional aspects in the tool use of non-human primates. Finally follows a general discussion.

Language Use in Human Beings and Non-Human Primates

As already mentioned, the ability to use language in the broadest sense may very well be the single most salient difference in manifest achievements between human beings and non-human primates. However, in order to make a fair comparison of language between human beings and non-human primates, we will exclude spoken language as such. While spoken language is indeed an important part of language use in human beings, certain physiological features (motor control of tongue and supra-laryngeal tract, Byrne, 1995, p. 165) constrain the abilities regarding sound production in non-human primates, whereby general language abilities and physiological requirements, at least to some extent, are confounded. Thus, it is no coincidence that with our specific purpose in mind we employ the term language *use*.

Given the physiological deficits present in great apes regarding sound production, researchers interested in language use seem to have concentrated on *sign language* and *concept formation*. In the following argument these two domains will be treated in turn.

Sign Language or Vocabulary

The development of the human vocabulary is truly impressive. The average normal infant produces his or her first words around their first birthday. By the age of six the number of known words has increased to approximately 10,000 (Bloom, 1998), and depending on the method of measuring applied, the vocabulary of a typical college student has been estimated to consist of up to 150,000 words (Miller, 1977, in Siegler, DeLoache & Eisenberg, 2006).

In non-human primates, the picture is radically different. For almost a century, researchers have explored the possibilities of teaching some kind of sign language to non-human primates (Byrne 1995; Tomasello & Call, 1997). To date the most impressive case of word learning in non-human primates seems to be the accomplishments of the captive-born pygmy chimpanzee or bonobo (*Pan paniscus*) Kanzi (e.g., Savage-Rumbaugh, Murphy, Sevcik, Brakke, Williams & Rumbaugh, 1993). By the age of 7 Kanzi knew the meaning of about 150 words as estimated in blind testing. One interesting aspect of the achievements of Kanzi is the way he learned words. Earlier attempts to teach signs or words to non-human primates were based on explicit and direct teaching from a human being to a great ape. One of the subjects of such endeavours was Matata – Kanzi's mother.

In the first 2½ years of Kanzi's life he received no training but observed the teaching that was directed towards his mother who generally faired rather poorly. Quite surprisingly, though, it appeared that Kanzi had profited substantially more from these instructions than his mother. At the age of 7 when he was given verbal instructions (e.g., "Pour the Perrier water in the milk"), Kanzi achieved approximately about the same level of correct responses as Alia, a 2-year old human child (59% correct responses for Kanzi vs. 54 % for Alia; Savage-Rumbaugh et al., 1993). While this is impressive in itself, one should note that a 2-year-old human child might not be the most obvious choice as an exponent for achievements in mature human beings.

One of the central demarcation lines when considering and comparing language abilities in human beings and non-human primates has been the ability actively to combine symbols in a way that reveals understanding of syntactic structure (e.g., Pinker, 1994) – which is often noted as a defining feature of language (Tomasello, 1994). For many years syntactic competence has been thought of as a domain simply beyond reach for non-human primates (e.g., Byrne 1995). However, very recent evidence with monkeys may have challenged this traditional view: Male putty-nosed monkeys (*Cercopithecus nictitans*) are, among other monkeys, known to produce acoustically distinct and loud calls presumably in order to inform conspecifics of dangers, such as approaching predators (Arnold & Zuberbühler, 2006). Arnold and Zuberbühler (2006) found that apart from such predator-specific calls, male putty-nosed monkeys regularly employed *combinations* of these distinct calls, often causing the group of monkeys to move. In subsequent experiments using recorded calls, combined calls were contrasted with distinct calls while monitoring the monkeys' group behaviour. The results revealed that combined calls did seem to have a specific semantic meaning to the group as they caused the monkeys to move over significantly larger distances than non-combined calls (ibid). Analogous combinations of calls with apparently specific meaning for conspecifics have also recently been found to be present in wild gibbons (Clarke, Reichard & Zuberbühler, 2006).

Such evidence obviously gives rise to the thought that some simple aspects of syntactic ability might be present in non-human primates. Hence, syntax may therefore not exclusively be human territory. However, the results could also be interpreted in a more cautious manner in which syntax may not be implied or needed. Note, that evidence indicating that two-component calls appear to have a specific semantic meaning for conspecifics may not, in our opinion, necessarily warrant syntactic *understanding* by neither producer nor receiver. The same level of competence may have been accomplished by simple trial-error learning. Whether syntax is truly beyond reach for non-human primates seems therefore to remain an empirical question to be explored further.

However, while evidence exists that non-human primates understand symbols, as well as reference, the jury is still out there regarding syntax. Obviously, this should not be taken as evidence that non-human primates are close to human beings in overall language use. Actually, it seems fair to say that the differences in magnitude regarding language use between human beings and non-human primates are no less than enormous. Furthermore, according to Berk (2006), there is no evidence to date that shows non-human primates are capable of producing complicated *and* novel sentences – a feat demonstrated daily even by pre-school children.

Concept Formation

What about concept formation then? A concept can be defined as a summary representation that constitutes the basic meaning or *intention* of a given notion (Mandler, 1997). According to Mandler (1997, p. 163) a concept answers the core question: “What kind of a thing is it?” In contrast, the *extensional* side of concepts deals with the question regarding “which things are tigers?” For many years the extension of a given concept was considered to be defined by some necessary and sufficient features that clearly and exclusively demarcated the given concept from other concepts (e.g. cars from bicycles or tables from chairs). This approach to concept formation, formalized by Frege (1952), was earlier called the Aristotelian or Classical view and is now at times called ‘the defining attributes view’ (Eysenck & Keane, 2005). One important feature of this Classical view is that all members of a given category are considered equivalent, that is, no car is more ‘car’ than other cars.

However, the Classical approach was severely criticized, first from philosophy and subsequently from psychology. In his *Philosophical Investigations* Wittgenstein (1958) argued convincingly - using ‘a game’ as an example - that it was simply impossible to specify the defining attributes of everyday concepts. Furthermore, from psychology empirical research on everyday concepts revealed that the typical user did not consider different exemplars of a given concept equivalent. Rather, there seemed to be an internal structure within a given concept indicating that some members of a given category (e.g., birds) were more *prototypical* (e.g., a robin) than others (e.g., a penguin). According to prototype theory, as this approach was called (e.g., Rosch, 1975; 1978), this aspect of concepts was called the *horizontal* dimension.

Prototype theory (Rosch, 1978) proposed and provided empirical evidence for a *vertical* dimension inherent in concepts, as well. Concepts were supposed to exist at three levels: Superordinate (e.g., furniture), basic level (e.g., chair), and subordinate level (e.g., bar chair). Another important criticism of the classical view from prototype theory was that even abstract, logical concepts (e.g., natural numbers) that actually *could* be defined in accordance with the criteria proposed by the Classical view were shown to possess prototypes (Lakoff, 1987).

Therefore, while the Classical view promised a beautiful, clear-cut and rule- based approach to concepts; the view was flawed by simply not corresponding to the concepts by which human beings live. However, it also should be noted that prototype theory is not the final word on concepts of adult human beings. Today, many researchers would insist that prototype theory would have to be accompanied by the *exemplar* approach (prototypes are usually specific exemplars, not just means of incidents) as well as, the *explanation* or *theory-based* approach (some conceptual distinctions are based on theory, not by resembling physical features; e.g., Wisniewski & Medin, 1994). Let us briefly look at concept development:

Empirical evidence from prototype theory indicated that the first words children learnt belonged to the basic level (Rosch, Mervis, Gray, Johnson & Boyes-Bream, 1976). However, prototype theory has not been successful in explaining how these concepts actually develop (Rosch, 1978). Besides, developmental psychologists have shown that children clearly establish concepts *before* they are able to provide a verbal account of these. As Mandler (1998) puts it: ‘Infants think before they speak.’ It appears that whether such preverbal concepts belong to the basic level depends, at least to some extent, on the method used to explore these concepts: For instance, if 3 to 4-month-old infants are shown visual stimuli, they typically dishabituate when watching an exemplar from another basic level category (e.g., a dog) as opposed to an exemplar from the basic level category to which the infants were habituated (Eimas & Quinn, 1994; Quinn, Eimas & Rosenkrantz, 1993). However, if older infants, say 7 to 11-month-old-infants, are allowed to manipulate the objects with their hands, they typically show prolonged investigation, when shown exemplars from another superordinate category (e.g., animals vs. vehicles), but not when presented to exemplars belonging to different basic level categories from the same superordinate level (e.g., horses vs. rabbits, or trains vs. busses) (Mandler & McDonough, 1993). To summarize, the concepts of human beings are not only highly efficient in ordering the world into suitable and cognitively economical concepts - they are also highly complex.

In non-human primates, the concepts are by all measures much more simple. Some studies have investigated the ability to sort abstract objects. For example, Garcha and Ettlinger (1979) studied whether chimpanzees, rhesus macaques and capuchin monkeys were able to sort wooden objects into three groups based on their shape, colour and size. The results were not impressive. None of the monkeys were able to arrange the objects above chance level within the first 100 trials. However, four of the five participating chimpanzees actually reached above chance level arranging – two within the first 100 trials and two within 650 trials (Garcha & Ettlinger, 1979).

In a more recent study on abstract categorization, Smith, Minda and Washburn (2004) investigated the categorization abilities of four male rhesus monkeys and 47 adult human students. The stimuli (presented on screens) could vary in the dimensions shape, colour and size with two options for each dimension. By means of feedback following each trial, the subjects were trained to categorize stimuli in accordance to six different types of pre-defined categories unknown to the subjects. Since the tasks were rather difficult, a substantial amount of trials were given. For each monkey 72,000 trials were carried out leading to a total of 288,000 trials. Each human subject was given 1,152 trials leading to a total of 54,144 trials. As expected, the results revealed that human beings learned the categories substantially faster than monkeys. However, what was probably more interesting were the results from the study in the second type of the six types of tasks instantiating a Boolian XOR problem to the subjects (e.g., if square, then white = A and black = B; if triangle, then black = A and white = B). When given this kind of tasks, human beings faired remarkably better than monkeys. According to Smith and colleagues, these results may indicate that monkeys build their categories exclusively by means of association and generalization. Human beings, in contrast, also employ *explicit rule learning* which appears to be a major advantage when dealing with XOR problems (Smith et al., 2004). In this respect, language use as such must be an effective tool when attempting to make rules explicit. Thus, explicit rule learning seems to be far more advanced in human beings than in monkeys.

While these results are far from convincing, it should be noted that such abstract objects are unlikely to have any functional significance to the participating subjects.

In a seminal study by Savage-Rumbaugh, Rumbaugh, Smith & Lawson (1980) objects with more direct significance for the subjects were used. Two language trained chimpanzees were taught to sort objects into groups of what human beings would consider as either ‘food’ or ‘tools’.

The two subjects learned fairly quickly to arrange the objects into these two distinct classes. Subsequently, the real objects were substituted with plastic tokens (lexigrams) corresponding to these categories. Furthermore, tokens referring to completely new objects were introduced to the categorization task. The results revealed that the two chimpanzees actually succeeded sorting even the novel tokens into the right categories as either food or tools. According to the authors, this indicated that the chimpanzees were able mentally to represent the referents of the lexigrams (Savage-Rumbaugh et al., 1980; for similar and more recent studies with baboons, see Bovet & Vauclair, 1998).

In more recent studies researchers have often used pictorial representations of the objects to be categorized. For instance, in a *same/different* design Wright, Rivera, Katz & Bachevalier (2003) investigated whether three capuchin monkeys could learn to indicate whether exemplars from categories (e.g., apples, buildings, cats, women’s faces, flowers etc.) belonged to the same or to a different category. All three capuchin monkeys eventually reached 80 % correct scores, but only after 32 sessions of 100 trials each (Wright et al., 2003). Besides the substantial number of trials necessary to achieve above chance level in such studies, there are also often large individual differences amongst the participating animal subjects (e.g., Tanaka, 2007; Vonk & MacDonald, 2004).

The results from the seminal study by Savage-Rumbaugh and colleagues led to another important aspect of concept formation in non-human primates: When scoring in relation to categories is successful in non-human primates, it is almost always related to what Rosch (1978) would call the superordinate level (e.g., Murai, Kosugi, Tomonaga, Tanaka, Matsuzawa & Itakura, 2005) whereas basic level categorization is rarely seen. However, in a recent error study of mental representations of symbols with two bonobos (of which Kanzi was actually one) by Lyn (2007), the evidence revealed that the subjects made hierarchical categorizations. Thus, basic level categorization may not after all be a uniquely human characteristic.

To conclude, great apes do seem to have some ability to form concepts, although their competence is far from being equivalent to that of human beings. Furthermore, if the objects – or at least their referent – have no functional significance to the non-human primates, their ability to categorize appears enormously restricted in comparison to human beings.

Tool Use in Human Beings and Non-Human Primates

The amount and diversity of tool use in human beings is truly impressive. Some of the tools basically work as extensions of the human body. Although cranes and excavators are far more complicated to construct and use than basic tools like shovels, spears, hammers, knives and axes, they all share the idea that they basically work as extensions of the human body by which they make it possible to carry out work far easier than without tools.

However, within the last decades an entirely different kind of tools has been developed, that is, software-based tools, like cell phones, laptops and automotive navigation systems. Contrary to other tools, these computer-based tools typically have a graphical user interface in which the physical constraints (e.g., gravity, continuity) govern our macroscopic ecological niche are put aside. On such graphical user interfaces icons or symbols disappear and reappear fairly unnoticed. Besides, such advanced tools share the feature that their most powerful and intended affordances (cf. Gibson, 1979) are hidden to the naïve subject. Although there is reason to believe that we ought to keep the physical constraints that rule in the 'real world' outside the graphical display in mind when designing such interfaces (Nørager, this volume), the ability to manipulate symbols abstracted from the physical basis seems mandatory in order to benefit from such advanced tools.

Tool use in non-human primates is markedly different. According to Byrne (1995), tool use in our closest relatives, the chimpanzees, is restricted as opposed to human beings in the following way – all being related to the range of methods when attempting to manufacture tools: No tools have been recorded made by addition of one item to another, and no tool has been made in the wild whose sole function is to make another tool (p. 96-97)

However, Byrne (1995, p. 97) acknowledges that individual examples of great apes using a sliver as a sort of a wedge in order to stabilize a loosely seated anvil stone before attempting to crack nuts with a hammering stone comes close.

While we endorse Byrne's conclusion, we would like to add that the difference in tool use between human beings and non-human primates should not be restricted to differences regarding the manufacturing processes, although these are definitely important. As outlined above, some of the *end products* themselves (i.e. software-based tools) manifest in modern societies are qualitative different from the tools used among non-human primates.

In summary, we believe it is fair to say that language use and tool use is substantially more advanced and sophisticated in human beings than in any other primate. Although these two areas may seem quite different at first glance, we shall argue that the superiority regarding these domains manifest in human beings may, at least partly, derive from a special ability that enables us to extract the functional properties of objects – an ability already present even in human infants and small children.

Extraction of Functional Aspects of Objects in Infants and Small Children

How do infants successfully organize the world into the meaningful categories and concepts underlying language? The answer to this question is, obviously, very complex, and several decades of studies of categorization and concept formation have reflected this complexity (Cohen & Cashon, 2006; Kingo, 2008). At present, one of the thriving areas of investigation regarding infant categorization and concept formation consists of studies on object-function. Object-functions are especially interesting since they are conceptually rich constructs that embody causal relations between objects properties, actions on objects physical outcomes and the goals of purposeful agents (Booth, 2006).

The investigation of object-function as a crucial factor in infant categorization and concept formation has seen many changes in the last three decades. In the mid-70’s, Nelson (1974) pioneered by putting forth the “functional core hypothesis”, proposing that 1-year-old children in their earliest language development would first form concepts about things in the world by experiencing them in interaction with other people, and then would later learn and generalize object-names on the basis of these concepts. The core of these concepts was proposed to be the *function* of the things, what they did and what could be done with them. Taking the concept of a ball or “the idea of ballness” as an example, Nelson proposed that over time the child would compare the various relations into which the ball enters and synthesize those relations or functions that are *invariant* across events (e.g. “rolls”, “bounces”, “is picked up”, “is tossed”, “is caught” etc.). This synthesis of “functions” would constitute a *functional core* that would enable the infant to represent the notion of a ball *between* different encounters instead of representing each new instance of a ball separately (Nelson, 1974). In retrospect such a perspective on concept formation was in accordance with the general *Zeitgeist* of the 70’s in this area of research (Nelson & Ware, 2002). Since then, though, the focus on studies of categorization and concept formation has moved from functional features to other object features such as visual static attributes of the objects *per se* or simple perceptual discrimination of pictures of various objects (e.g. Eimas & Quinn, 1994; Quinn, Eimas, & Rosenkrantz, 1993).

In recent years, a renewed interest in object-function has emerged. One of the shortcomings of the research in object-function in the first decades was the inability properly to separate functional attributes from other object attributes (Nelson & Ware, 2002). Now, due to the tremendous development in infant research methodology, such more sophisticated studies have become feasible, and object-function is once again moving onto centre stage. The new multitudes of methodologies have led to an increased need for a clear definition of the term object-function. Nelson has suggested that at least four different variations of the notion of function emerge from the child's point of view:

Actions on things, for example, throwing balls. This aspect conforms to Rosch's emphasis on common motor movements of persons engaged with the objects.

Independents activity of the things themselves, for example, a barking dog. This aspect may help to define animates versus inanimates.

Reaction of a thing to an action on it, for example, the rolling of a ball after it is pushed, reflecting a cause-and-effect relation between two actions or between an action and an end state.

The use (idiosyncratic or conventional) of a thing for human purposes, for example, drinking from a cup. This aspect reflects the relation of an object to goal activities. Conventional uses is the definition often applied to concepts of artefacts in discussions of conceptual understanding and object naming, but may not be the function that a child will identify as significant. (Nelson, 1979 cf. Nelson & Ware, 2002, p. 164-165)

Keeping in mind that object-function comes in different guises, we now present a small but relevant selection of contemporary studies and theories targeting object-function. We do this in order to emphasize the important position the concept of object-function has (re)claimed in the field of infant categorization and concept formation.

Some of the earliest examples of the more contemporary approach to object-function were the studies by Kelly Madole and colleagues in the mid-90's. These authors were interested in the assumed correlation between form and function in infant categorization (Madole, Oakes, & Cohen, 1993; Madole & Cohen, 1995). In one study, Madole, Oakes and Cohen (1993) let infants manipulate different objects in an object-examination task. An infant would be familiarized with a single object and was subsequently given a modified object to examine. Form and function were studied as separate factors since the modified object differed from the first in either form, function or in form *and* function. It was then measured if and how much the infant increased its attention to the modified object relative to the first object (a typical “out of category”-response from infants) and relative to a completely novel object. The stimuli objects were constructed from Lego® building blocks (see figure 1 for examples) and crossed two different shapes with two different functions resulting in four different objects. One function was *rolling* (the wheels were fixated on half of the objects to disable this function) and the other was *shaking* (half of the objects made a rattling sound when shaken). The novel object was a “mooing box” that mooed when it was tilted.

Figure 1

Pictures from Madole, Oakes & Cohen (1993)

The experimenters found, that 10-month-olds responded to changes in form only, while 14-month-olds responded to changes in form *or* in function (Madole et al., 1993). In the second experiment of this study, 10-, 14- and 18-month-old infants were familiarized with two objects in which a consistent form-function relationship was maintained. Infants were then tested with (1) a correlated object that maintained the familiarized form-function relationship, (2) an uncorrelated object that violated this relationship and (3) a novel object. The 10- and 14- month-old infants increased attention only to the novel object, while the 18-month-olds increased attention to the uncorrelated object, as well as the novel object.

From these two experiments, it was concluded that there seems to be a developmental progression from attending only to the form of objects, to attending to form and function as separate properties, and finally to attending to the *relationship* between form and function (Madole et al., 1993).

In later studies, Madole and Cohen (1995) investigated whether the perceived form-function correlations depended on specific parts of the objects. In the first study, 14- and 18-month-old infants were found to pay attention to the correlations of the object-function and a specific object part. In studies two and three, objects were presented in such a way that the form of one part correlated with the function of a different part (contrary to the correlations most often found in real objects where the function of a specific part tends to correlate with the form of that specific part). Only the *younger* infants attended to the form-function correlations in these studies. This result was seen to suggest that the older children had acquired constraints on the kinds of correlations they recognize – this properly to adapt to or "tune in to" the typical correlations of real objects (Madole & Cohen, 1995). This trend has been confirmed by other studies such as Träuble and Pauen (2007) where 15-month-olds were found to acquire more *specific* functional knowledge from novel objects compared to 12-month-olds who primarily acquired *general* functional knowledge.

The research described above from the labs of Oakes, Madole and colleagues has partly challenged the functional core hypothesis suggested by Nelson. While maintaining that functional aspects play an important role in the formation of object concepts, these authors did not find any evidence of infant attention towards functional aspects before the age of 14 months. The functional core hypothesis rests on the assumption that functional aspects are essential in the concept formation of the 1-year-old, which in turn presupposes that infants are able to pay attention to these aspects at least from this age. However, in spite of the age discrepancies, the above-mentioned work by Oakes, Madole and colleagues confirms the relative importance of functional information in infant cognition and represents a "microanalytic" and more detailed approach to the study of object-function (Oakes & Madole, 2003). These two studies, though, primarily target the *fourth* notion of function as suggested by Nelson (described earlier).

Evidence regarding the importance of function in the sense of Nelson's *first* notion ('action on things') comes from Linda B. Smith (2005). She found that making 2-year-olds move an object horizontally or vertically defined the horizontal or vertical axis as the main axis of elongation and systematically changed the range of shapes seen as familiar. In other words, the child's own movement of the object affected the child's categorical responses even with very simple movement patterns (horizontal or vertical lines). Interestingly, making the child observe an adult perform the same movements did *not* affect the child's subsequent categorical responses. In a somewhat similar experiment, symmetrical or asymmetrical movement of a symmetrically ambiguous object effected whether or not this object was judged to be more or less symmetrical (symmetrical movement resulted in "symmetrical" judgements and vice versa). Again, watching others perform the actions did not change the range of shapes children judged to be members of the same category (ibid.). All in all, this study points to a very direct connection between *actions* on objects and the *categorization* of these objects. This connection has also been pointed out in other kinds of studies such as studies on action planning and the learning of rules and regularities in infancy (e.g. von Hofsten, 2007).

The distinction between self-action and the actions of others relates to the distinction between Nelson's first and third notion of function versus the second notion. That is, the distinction between actions on objects and the object's reaction to that action, on the one hand, and the independent activity of objects, on the other. Infants seem to be able to make this latter distinction at a very early age. Markson and Spelke (2006) found that 7-month-old infants were able to differentiate between the self-propelled motion of an object and the movement of an object by the experimenter's hand. Furthermore, infants from the same age group were able to retain the specific movement characteristics (self-propelled or passively moved) of different objects for some time (15 min.), indicating that the learning is robust and infants' expectations about self-propelled motion are enduring (ibid.). This study provides indirect evidence that infants are able to extract and retain different kinds of functional information from a very early age – well within the first year of life as originally proposed by Nelson (1974).

Mareschal and Johnson (2003) have argued that information on object-function plays another crucial role even earlier in development. They argue that young infants (4 months of age) are limited in the kinds of information they are able to integrate simultaneously. Specifically, the authors describe how the visual information of objects can be processed by two different neural "streams" or pathways in the cortex: The *dorsal* stream which primarily processes information on the location and movement of objects, and the *ventral* stream which primarily processes information on other object features such as shape, colour, texture, etc. At four months infants are not fully able to integrate these two information streams and are therefore forced to act based on only one of the two available kinds of information. The relevant point here is that it seems to be the object-function that determines which one of the neural pathways will dominate the infant's behaviour or actions towards the object. Three-dimensional objects, for instance, tend predominately to activate the dorsal stream since they afford handling and because location and movement are essential in such acts. However, two-dimensional pictures tend predominately to activate the ventral stream since such pictures do not afford handling and may therefore primarily provide the infant with information on the non-functional object features such as surface pattern and texture (ibid.). This is yet another example of the central role of object-function in early human infancy.

How do these different aspects of object-function play a role in concept formation? As mentioned earlier, Mandler (1997) has proposed that a concept in effect answers the question: "What kind of a thing is it?" Throughout her work, Mandler has maintained that conceptual information is not directly about the perceptual properties of an object *per se* but has more to do with what an object *does* or what it can potentially do (a door swings, opens and closes; a dog barks, runs, bites, etc.) (Mandler, 2004). Being an influential researcher in this area, Mandler has had many disputes with other researchers, but this claim of the primacy of object function in concept formation has taken few beatings and has spurred the greatest agreement among developmental researchers (Carey, 2000; Gibson, 2000; Murphy, 2004; Nelson, 2000; 2004; Quinn & Eimas, 2000; Quinn, 2004; Reznick, 2000; Shutts & Spelke, 2004; see also Kingo, 2008). Function, it seems, is closely tied to concept formation and thereby language.

By now, we hope it is evident that the kind of information collectively termed object-function is a crucial factor in early human categorization and concept formation, or at least the object of intense interest from a range of developmental researchers at present. Infants very rapidly extract and use information on object-function for many different purposes, among these the formation of concepts and mastery of their environment. The general trend is that more and more functional information becomes available with development. At the same time, though, the pool of information that is actually processed will meet an increasing amount of constraints due to an increase in background knowledge (Madole & Cohen, 1995; Oakes & Madole, 2003).

Extraction of Functional Aspects of Objects in Non-Human Primates

The motivational aspect is obviously very important when considering tool use in non-human primates (Tomasello & Call, 1997). Contrary to the prominent curiosity in human infants regarding objects in general, objects for non-human primates are primarily interesting when they are found to serve a direct purpose (Byrne, 1995). In that respect 'Curious George' should have been a child, not an ape! Thus, when investigating tool use in non-human primates, the functional aspects of the objects present are highly relevant indeed. In the present context one may ask how non-human primates fare in comparison to human beings when attempting to extract functional aspects of objects?

In a recent paper by Spaulding and Hauser (2005), the authors summarize the last decade of studies investigating what non-human primates understand of the tools they use, by stating that while the animals are clearly sensitive to the perceptually relevant features of the tools, they simply appear more or less to *lack* understanding of the physical properties the tools might possess (for instance, by choosing a perceptually similar tool, but made of an inadequate material – e.g. rubber instead of plywood; Povinelli, 2000, cited in Spaulding & Hauser, 2005).

Thus, the importance of functional aspects of tool use in non-human primates in comparison to human beings seems to contain a paradox: On the one hand, it seems unavoidable to take functional aspects of objects into account when considering tool use in non-human primates, since objects with no obvious functional relevance will have a very limited interest to the subjects. On the other hand - and contrary to what is the case for human beings - non-human primates display severe difficulties in disentangling the functional *core* of a given object; for great apes the functional aspects appear to be bound to featural aspects while 'hidden' functional properties predominantly remain beyond reach.

Discussion

We have now contended that the ability to extract functional information rapidly from objects is a crucial and early developing ability of human infants. For humans, this ability is central in the formation of concepts and in the development of tool use. We find that contemporary research on object-function in developmental psychology makes it clear that functional information plays a crucial role in infant cognition on several levels, and that functional information is a factor that constrains *and* expands the pool of possible interpretations of the physical surroundings, thereby partly shaping the human approach to the world. Furthermore, the contemporary approach to object-function shows us that infants do indeed possess the necessary skills to build representations similar to the functional cores suggested by Nelson (1974).

In non-human primates, it seems, functional information does not have the same impact on cognition. Although, non-human primates display some knowledge of object-function, this knowledge seems to be very restricted compared to humans and very purpose-specific. Contrary to human beings, it does not seem meaningful to describe the information non-human primates possess on objects-functions as a *functional core*. Functional cores are per definition complex since they are summaries of *various* actions with the same kind of objects. This is a kind of representation that is very different from what seems to be better described as somewhat simpler object-action-goal associations in the non-human primate world. Functional cores are *abstractions* and as such they allow humans to apply functional information beyond the present moment or specific problem. The implications and consequences of such ability are by no means small, as we shall now argue.

One influential approach to the meaning of objects is the theory of affordances by Gibson (1979). *Affordances* are what the world offers the individual. Depending on the physical characteristics, the skills available and the task at hand, a given subject can extract a range of different affordances from a given object. In the present context, it may be argued that affordances are more or less equivalent to *functional* characteristics of objects. The Gibsonian approach seems fairly straightforward when considering functional characteristics – or affordances – that are prominent to a given subject (e.g., large trees may offer shelter from the rain for creatures searching for that). However, other functional characteristics or affordances may not be likewise salient to the naïve subject. The functional characteristics or affordances of many man-made artefacts are not obvious unless you *know* what they are made for. Consider for instance artefacts like washing machines, computer routers or cell phones. While such objects may have many different and valuable affordances they were each made with a *specific* purpose in mind (e.g. Tomasello, 1999), and due to the complexity of the objects at stake, these purposes are not easily specified and subsequently ‘picked up’ directly in the visual array. Nevertheless, contrary to non-human primates, human beings have no problems using such artefacts. Note, that while non-human primates had difficulties separating functional characteristics of tools from their physical appearance, this is learned in late infancy in human beings.

Obviously, there is likely to be many requirements for a given subject in order to succeed in extracting the functional properties of a cell phone. Our point is simply that the superiority of human beings in this regard may, at least partly, derive from the ability to abstract functional characteristics that may – or may not – be prominent in the visual array.

The reader may consider highly advanced software-based artefacts as cell phones and equivalent as unfair items to base the arguments upon, since such objects are not only characterized by having somewhat ‘hidden’ affordances but also by requiring symbol manipulation in order to be handled – which is, as we have argued, another area in which human beings excel in comparison to other species.

However, the best example underscoring the claim that human beings appear to be light years ahead of other species in this respect may be present in the symbolic handling of other and much simpler objects. Let us take a brief look at *pretend play*. The stereotypical example of pretend play is when the human child at 1½ years begins to *pretend* to use a given object for a completely different purpose – as for instance when he or she uses a banana as a telephone, or a piece of wood as a car or a gun (e.g., Leslie, 1987). Note, that such applications are *not* based on inherent functional characteristics of the objects on which the pretended implementation takes place, nor necessarily by physical resemblances between the objects. Pretend play is not only impressive by implying the fragile emergence of meta-representations, as argued by Leslie (1987); pretend play can also, in our opinion, be seen as a fascinating manifestation of the ability to abstract a functional core of a given object (e.g., a cell phone) and pretend the implementation of this functional characteristic in an entirely different object. If the infant were unable to abstract the functional core of a given object, we would seriously doubt that pretend play would or could take place at all. When considering the necessary cognitive requirements in order to be able to think about and make new tools, the imaginary abilities manifest in pretend play must be a very powerful ‘mental tool’ indeed. Our claim is supported by the concluding paragraph by Tomasello and Call (1997, p. 70) in a brief section on symbolic play: “Apparently other species of primates have not been given the opportunity to display these same “symbolic” behaviors.” Thus, we believe that the ability to abstract functional cores of objects may be an indispensable prerequisite for the superior tool use manifest in human beings as opposed to other species.

Let us now turn to language. As stated previously, the cognitive semantics of language may be the “fairest” area of comparison between the language of human and non-human primates since the ability of language production *per se* is largely governed by the specific physiological constitution of each species. We contend that an important factor in the excellence of human semantics may be our superior ability, not only to extract, but also to *abstract* functional information from experiences with our surroundings. The abstracts or summary representations of objects and events provide us with virtually context-free concepts, for instance, in the form of functional cores (Nelson, 1974; 1985) or other results of function/meaning analysis (e.g., Mandler, 1997; 2004). As with tools, the richness of functional information in our concepts allows us to use them very flexibly. Again, since our concepts are constituted by a range of functions or utilizations, we are able to apply these concepts in many different situations with very little effort. This flexibility may be one of the communication highlights of language as it allows for infinite word-word relations and complex (conventionalized) meaning "packages" (syntax or grammar). Naturally, language is more than functional information in a specific format, but language, as we know it, seems impossible without our inherent aptitude for discovering functions, and as far as we know, we are the only species with this highly developed aptitude. Non-human primates do not seem to be able to produce complicated or novel sentences or to be able actively to combine symbols in this flexible way (fully in parallel with their somewhat inflexible tool use). As the picture unfolds, it becomes more and more evident how keeping track of a multitude of functional characteristics for each object experienced gives human beings a huge advantage in the formation of concepts. At present we are still uncovering the nature of this ability in humans and in human infants in particular, but at this point we do know that functionality shapes human cognition from a very early age. Our functional aptitude provides us with a kind of multifunctional "mental tools" which enables us to contain, shape, produce and communicate our impressions of the world in a unique way.

Language use and tool use are somewhat different domains in which human beings excel in comparison to other species. In this chapter we have argued that the ability to extract and abstract the functional characteristics of objects may serve as a means to facilitate the excellence in human beings as opposed to other species in the aforementioned areas. In this vein we therefore welcome the renewed interest in infants' understanding of functionality in objects – an area that has remained central for a century within the field of comparative psychology.

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CHAPTER FIVE

THE HUMAN ABILITY TO SINGLE OUT AND TRACK SPECIFIC OBJECTS THROUGH SPACE AND TIME: ORIGIN AND APPLICATION

PETER KRØJGAARD

Abstract: This paper pursues the origin and application of the human ability to single out and track specific objects through space and time. Evidence from object based visual attention in adults, as well as, infant research on object individuation is reviewed, indicating that spatiotemporal information is important when tracking objects. However, recent results from comparative research indicate that basic aspects of object individuation may also be prominent in some non-human primates. Thus, when adult human beings display elaborated understanding of cultural artefacts beyond the level manifest in infants and non-human primates, some additional skills far beyond object tracking here-and-now must be required. It is proposed that the ability to abstract spatiotemporal threads of specific objects may be the uniquely human skill that fulfils this requirement.

"You are beautiful, but you are empty," he went on. "One could not die for you. To be sure, an ordinary passerby would think that my rose looked just like you—the rose that belongs to me. But in herself alone she is more important than all the hundreds of you other roses: because it is she that I have watered; because it is she that I have put under the glass globe; because it is she that I have sheltered behind the screen; because it is for her that I have killed the caterpillars (except the two or three that we saved to become butterflies); because it is she that I have listened to, when she grumbled, or boasted, or even sometimes when she said nothing. Because she is *my* rose. […] It is only with the heart that one can see rightly; what is essential is invisible to the eye." (Saint-Exupéry, 1996, p. 68).

Introduction

Considering everyday objects like nails, pieces of chalk, plates or ashtrays, it may not make any difference whether the object located on the table here-and-now is exactly the *same one* (numerical identity, Strawson, 1964) as the one encountered on the table five minutes ago, *or* just another identical looking exemplar of the *same kind* (qualitative identity, Strawson, 1964). However, when it comes to heirlooms, original pieces of art, favourite toys, pets, friends, children, loved ones – or the precious rose in *The Little Prince* - the difference between the same object and a replica becomes of paramount importance. Thus, in their everyday lives adult human beings are indeed capable of singling out and tracking specific object through space and time.

So one obvious question is: What is the origin of such ability? Here I shall attempt to pursue this question. In anticipation, I will present evidence and arguments that, on the *one* hand, suggest that the ability to single out and track specific objects through space and time can be traced back to infancy, as well as, to some extent dates back to our non-human primate ancestors; on the *other* hand, adult human beings seem to exploit this ability far beyond the level manifest in infants and non-human primates. I shall propose that when adult human beings excel in comparison to infants and non-human primates in their use of such competence, it may derive from the ability to *abstract* spatiotemporal threads of objects from one domain to another.

The paper is structured as follows: The *first* section of the paper is devoted to a brief outline of the different kinds of information that is usually considered relevant for keeping track of objects. The *second* section presents evidence from studies on object based visual attention in adults. The *third* and most comprehensive section focuses on infant research on object individuation. The *fourth* section is a brief outline of some of the few studies on object individuation that have been conducted with non-human primates. The *fifth* and final section offers examples of how the ability to single out and track specific objects paves the way for important achievements in early childhood, as well as, in adulthood: Regarding early childhood, I shall argue that such an ability is a necessary prerequisite for concept formation and word learning. As for adulthood, I will attempt to argue that adult human beings exploit this ability far beyond other primates in our appreciation of man-made artefacts and culture in general. Finally, I will propose what might be responsible for this uniquely human feature.

Featural and Spatiotemporal Information of Objects

It is commonly agreed that in order to keep track of a given object over time (e.g. a pen or a bicycle) one has to pay attention to at least *two* different kinds of object information, that is, featural and spatiotemporal information (e.g., Krøjgaard, 2004; Mammen, 1996, 2002; Xu, 1999).

Featural information refers to information regarding an object's specific properties of which colour, size, shape and texture are usually the most salient (Wilcox, 1999) whereas *spatiotemporal* information refers to basic information regarding object location and object motion. Adults seem to possess rather sophisticated knowledge regarding what solid objects at a macroscopic level can and cannot do.[1] For instance, an object without support will fall downwards until it meets a solid surface; one distinct object cannot occupy two different locations at the same time; two distinct objects cannot occupy the same location at the same time; objects move continuously in space and time, etc. (Spelke, Breinlinger, Macomber, & Jacobson, 1992; Xu, 1999). However, although our spatiotemporal knowledge may seem obvious and trivial, it is rarely reflected upon in everyday conversation. Only when our tacit expectations are violated, for instance when we cannot find our keys where we thought we left them, or when a competent magician demonstrates his tricks to us, our firm belief in spatiotemporal information becomes salient.

Cognitive Psychology: Approaches to Object Tracking in Adults

For quite some years featural information of objects was given significantly more attention within the field of cognitive psychology than spatiotemporal information (Krøjgaard, 1999b; Mammen & Krøjgaard, 2008). This was, for instance, evident in the seminal categorization studies by Bruner, Goodnow and Austin (1956). This intermediate neglect of the importance of spatiotemporal information in the earliest years of cognitive psychology is likely to have been inspired by the then dawning view that the human being could, or even should, be conceptualized as an information processing system - i.e., a computer (Gardner, 1987). Given that computers are excellent tools for realising featural representations (e.g. implemented in semantic networks) whereas time and space are less

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[1] With the notion 'macroscopic level', I refer to solid objects at everyday-size like tennis balls, cups, and cars. At the quantum physical level the rules constraining object location and object motion may be substantially different.

intuitively obvious for a non-locomotive, stationary system, this tendency is probably not surprising. Thus, for some years, featural object information was considered to play the primary role within the field of cognitive psychology – also when attempting to keep track of specific objects (Krøjgaard, 1999b; Mammen, 1996).

However, in more recent years the understanding that featural information should play the primary role when adults categorize and track objects has been challenged from at least three different sides: (a) Common sense arguments; (b) evidence from experimental studies on object based visual attention in adults; and (c) formal accounts of the necessary prerequisites in order to make categorical judgements. These three challenges will be treated in turn.

Common Sense Arguments

As already stated, category membership was for some time considered to be exclusively based on the features of objects. However, the specific case of demarcating a category with only *one* member seems to give rise to serious problems in this respect. According to Pylyshyn (2001), human beings are bound to make use of some additional pre-conceptual visual indexing mechanism in order to be able to establish such a category. For instance, he writes:

> If we could only refer to things in terms of their category membership, our concepts would always be related only to other concepts (the concepts for categories) and would never be grounded in experience. […]. If our visual representations encoded a scene solely in terms of concepts or categories, then we would have no way to pick out or refer to particular individuals in a scene except through concepts or descriptions involving other concepts, and so on (Pylyshyn, 2001, p. 129).

Thus, given the fact that human beings are indeed capable of establishing categories consisting of just one specific exemplar (e.g., the category of blue pens given to me by my grandfather), some kind of additional mechanism that goes beyond object features is simply necessary.

Empirical Evidence from the Multiple Objects Tracking Paradigm

The results obtained by the so-called *Multiple Objects Tracking* (MOT) paradigm have provided *empirical* evidence to support the claim that human beings are clearly capable of tracking specific objects through space and time without relying on object features or properties. In the MOT paradigm adult subjects are usually shown from 8 to 24 two-dimensional simple and completely identical objects on a computer screen. A small subset (the target objects) of these objects is then highlighted for a few seconds, and the subjects are instructed to pay specific attention to these target objects. Subsequently, the highlighting is removed, leaving all objects identical after which a test follows: All objects begin to move around on (apparently) random paths. After a while all objects stop and the subjects are typically asked either (a) to point out the target objects, or (b) state whether a given object was a target object or not. Results obtained with the former of these tasks revealed that subjects were perfectly capable of keeping track of up to four or even five objects (e.g., Sears & Pylyshyn, 2000; Yantis, 1992). As for the latter task, subjects typically produced the correct answer in at least 85% of the trials (e.g., Green & Bavelier, 2006; Pylyshyn & Storm, 1988).

Thus, the results derived from the MOT studies convincingly demonstrate that human beings are perfectly capable of keeping track of specific objects while *not* relying on the features of the objects. The empirical evidence obtained in the MOT studies simply rules out the idea that object features should be sufficient, since all objects displayed are completely *identical*. Hence, in these studies subjects must - in order to fare successfully when keeping track of specific objects - make use of *other* sources of information than featural information.

One obvious question entailing the results derived from the MOT studies is what kind of mechanism could possibly perform such a task? Pylyshyn’s (1989, 2001) own candidate is the ‘fingers of instantiation’ mechanism, or in short FINST. According to Pylyshyn, the FINST mechanism, or ‘visual index’ is equivalent to a pointer or ‘mental finger’ that can be locked on or assigned to objects in the visual field. Two specific properties of the FINST mechanism are central. The first is that although the mechanism is supposed to track objects, it does no more than that; no *description* of the tracked objects is provided. Consequently, the FINST mechanism works at a preconceptual level. The second important feature of the FINST mechanism is that these visual indexes are supposed to be ‘sticky’ – which means, that when an object moves, the visual index moves along (Pylyshyn, 1989, 2001).

To summarize, in addition to common sense arguments, convincing empirical evidence shows that adults are capable of tracking specific objects through space and time, and they must do so by relying on some kind of spatiotemporal information; featural information alone is simply insufficient given the nature of the MOT tasks.

Formal Accounts of the Necessary Prerequisites in Order to Make Categorical Judgements

In a now seminal study Bruner and his colleagues showed that adults made categorical decisions by exclusively relying on featural object information (Bruner et al., 1956). However, by means of logical algebra, an axiomatic system and general topology, Mammen (1996) has convincingly argued that the results obtained in the study by Bruner and his collaborators (Bruner et al., 1956) are only valid if the number of objects to categorize amongst is finite, which in practical terms means *countable*. However, in the everyday world outside the laboratory, the number of relevant objects is not at all finite. Under circumstances where the number of objects on which to base the categories is beyond practical countability, Mammen (1996) has shown that featural information is insufficient; we will have to rely on spatiotemporal information too.[2]

Can this really be true? The following fictitious example may serve to illustrate the typical neglect of spatiotemporal information in our everyday thinking: Imagine a student who leaves his bicycle just outside the main entrance of the Department of Psychology in Aarhus. Later the same day, the student returns to pick up his bicycle in order to go home. How does he manage to find his specific bicycle among the many other bicycles also placed outside the department? A fairly straightforward answer would be that he looks for a bicycle with the same shape, colour, size, and brand, etc. as the one he happens to own. Following this account, the student seems to rely predominately, if not exclusively, on featural information in order to find his bicycle. Such an answer is not entirely wrong, but it is not completely correct either. What is forgotten in this chain of thought is that the student has already made a crucial (although often unreflected) decision *before* he attempts to track down the relevant features of his bicycle: He has chosen to look for his bicycle at the right global location (that is, outside the main entrance). He is not looking for his bicycle in Kansas or Berlin, but at the specific location in Aarhus, where he left it, and this strategy reduces the number of bicycles to choose from drastically. This may seem trivial but it is not. The point is, the decision about choosing the right location for the search for the bicycle is not based on featural, but on spatiotemporal information. However, choosing the

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[2] Mammen's (1996) axiomatic system is comprehensive and cannot be given here. However, a more condensed version of the theory is on its way (Mammen & Krøjgaard, 2008).

right location seems so obvious and trivial that we tend to neglect, or even forget, the importance of such competence.

To summarize, from the field of cognitive psychology that investigates adult cognition, converging evidence exists from at least three different approaches that - contrary to earlier theories - featural information is not sufficient information when human beings attempt to single out and track specific objects through space and time.

Evidence from the Cradle: Infant Research on Object Individuation

In order to fully disentangle a given phenomenon manifest in adult human beings, one is very likely to benefit from studying the phenomenon in question as it evolves through the ontogenesis (Krøjgaard, 2005). Can infant research shed light on the development of the general purpose tool of being able to single out and track specific objects through space and time? The answer to this question seems to be a clear “yes”.

Setting the Stage: The Heritage from T.G.R. Bower

T.G.R. Bower was a pioneer in at least two respects. First, he was one of the first infant researchers to insist on using tasks where gross motor achievements were not the key dependent variable. Second, Bower argued and demonstrated convincingly that the issue of object identity was an important and worthwhile research domain – also for infant researchers (Krøjgaard, 2004). Inspired by Michotte’s (1962) work with adults, Bower began to present events like the following to infants (see Fig.1).

Figure 1.

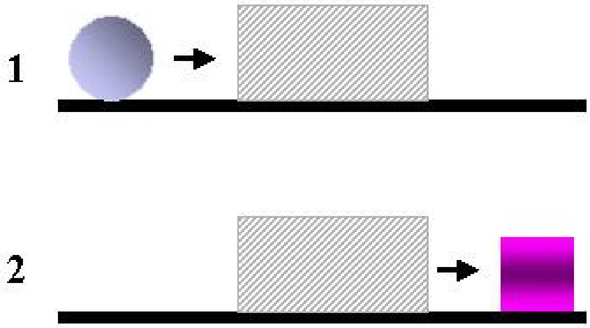


Figure 1. Schematic representation of a basic scenario in which one object moved behind an occluder followed by the appearance of a differently looking object on the other side of the occluder.

In principle the displayed scenario can be interpreted in at least two distinct ways. One might think that the ball remains behind the occluder while the cube moves into vicinity. Alternatively, one might parse the sequence as involving a ball turned into a cube – i.e. the so-called ‘tunnel effect’. According to Bower, the key question in order to decide between these two interpretations is as follows: Does the event involve *one* or *two* distinct moving objects (Bower, Broughton & Moore, 1971)? Note how the simple surprise reactions to the scenario displayed in Fig.1 do not inform the experimenter about which of the two interpretations outlined above actually causes the surprise reaction. Thus, while Bower succeeded in making object tracking an important and worthwhile field of infant research and successfully specified the important question regarding the number of objects present, he ultimately failed to present a convincing design that provided “answers” from infants to this specific question. Fortunately, a quarter of a century later Xu and Carey (1996) actually managed to devise such a design.

Object Individuation in Infancy

As we will see in the following, Xu and Carey (1996) attempted to provide an answer to exactly this specific question put forth by Bower, namely, how many objects are present in a given scenario? Today, studies that address this specific question are usually referred to as studies on *object individuation*. Object individuation is defined as the ability to decide the number of distinct objects present in a given scenario (Krøjgaard, 2004). In their now seminal study, Xu and Carey presented 10-month-old infants to a basic scenario in which two objects (e.g. a ball and a cup) moved in and out, one at a time, from behind a centre placed occluder (see Fig. 2).

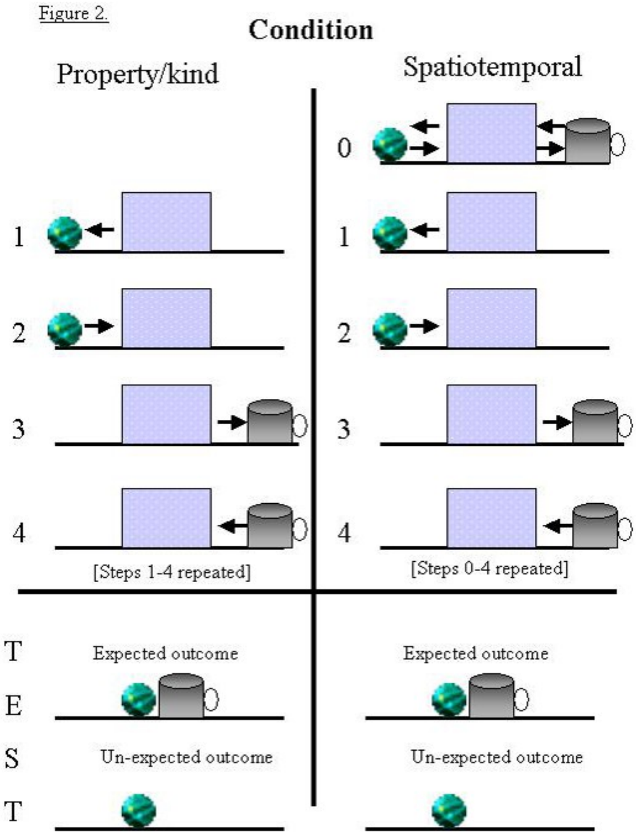


Figure 2. Schematic representation of the Property/kind and the Spatiotemporal condition of the Xu and Carey (1996) study.

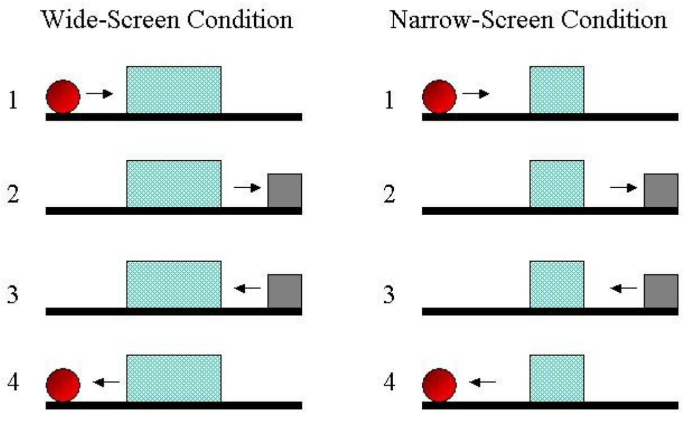
Infants were assigned to one of two slightly different conditions of which the introduction sequences differed. In the property/kind condition the objects were never shown simultaneously but only *one* at a time. However, in the spatiotemporal condition *both* objects were initially presented at the same time. Subsequently followed a test shared by both conditions. The screen was removed revealing either an *expected outcome* (both objects present) or an *un-expected outcome* (only one object present) in balanced order. By means of the so-called violation-of-expectation (VOE) paradigm, the infants' looking time was measured and analysed. The results revealed that whereas the 10-month-old infants in the spatiotemporal condition reacted with surprise (looked relatively longer) when one of the objects was missing, their same-aged peers in the property/kind condition did not. Thus, when provided with unequivocal spatiotemporal information about the number of objects present, the infants succeeded in individuating the objects, whereas when spatiotemporal information was ambiguous and the infants had to rely on featural object information, they *failed* to individuate the objects. The results obtained by Xu and Carey (1996) have been replicated in a number of studies using similar designs that apply the VOE paradigm (Bonatti, Frot, Zangl, & Mehler, 2002, Experiment 3; Krøjgaard, 2000; 2003) as well as, in manual search tasks (Feigenson & Carey, 2003; Van de Walle, Carey, & Prevor, 2000; Xu & Baker, 2005; Xu, Cote & Baker, 2005).

Thus, on the surface, the results derived from Xu and Carey's studies (1996) and their replicators seem to indicate that spatiotemporal information is primary to featural information when infants attempt to individuate objects. However, Wilcox and Baillargeon (1998a) have argued that the immediate superiority of spatiotemporal information as opposed to featural information may be task dependent and only manifest when task demands are high. Note how the design employed by Xu and Carey (1996) forces the infants to *remember* what happens in the introduction in order to be able to come up with the correct 'answer' in the subsequent test. Removing a screen and revealing a single object behind the screen is only surprising provided that the subject is aware that a different number of objects (e.g. two objects) *should* be present behind the screen. Such a demanding design is by Wilcox and Baillargeon coined an *event mapping* design, because the subject will have to 'map' information obtained in a proceeding introduction onto the test in order to respond successfully (Wilcox & Baillargeon, 1998a).

This cognitively demanding event mapping kind of design is contrasted with a less demanding design, named an *event monitoring* design, in which everything takes place in a single on-going sequence.

Thus, in the event monitoring design the infant will, at least in principle, be able to parse the relevant information just by ‘monitoring’ the sequence here and now; no ‘mapping’ from previous introduction sequences is needed (Wilcox & Baillargeon, 1998a). The clever wide-screen/narrow-screen design deviced by Wilcox and Baillargeon (1998a) serves as an illustrative example of event monitoring designs:

Infants 9.5 months of age watched a basic scenario in which a ball moved consecutively from vicinity to a hideout behind a centre located screen from where ‘it’ (apparently) re-appeared as a box and *vice versa* in a single on-going sequence. The infants were allocated to one of two different conditions (see Fig. 3).



Steps 1-4 are repeated until trial temination

Figure 3. Schematic representation of the wide-screen/narrow-screen design employed by Wilcox and Baillargeon (1998a).

In the *wide-screen condition* the screen used was sufficiently wide to hide both objects at the same time. However, in the *narrow-screen condition* the screen was so narrow that both objects due to their combined width clearly could *not* be hidden at the same time behind the screen. Using the VOE paradigm, the reasoning was the following: If based on the sizes of the objects, the infants reasoned that both objects could be simultaneously hidden behind the wide screen, but *not* behind the narrow screen, then the infants in the narrow-screen condition should look reliably longer at this test event than their same-aged peers in the wide-screen condition. This was exactly what the results revealed, and similar results were subsequently obtained with 7.5-month-old infants (Wilcox & Baillargeon, 1998a, exp. 3 and 4) and 4.5-month old infants (Wilcox & Baillargeon, 1998b).

Thus, the results obtained by means of the wide-screen/narrow-screen design have revealed that when the cognitive demands are reduced, then infants below 10 months of age are indeed capable of individuating objects by relying to a large degree on featural means.

It should be noted that while Xu and Carey (1996) under what might be considered cognitively demanding conditions made a direct comparison between infants' use of featural and spatiotemporal information, Wilcox and Baillargeon (1998a, 1998b) - while reducing the cognitive load - only investigated infants' attempts to individuate objects by featural means. Thus, until recently no one had succeeded in conducting a direct comparison of infants' use of featural and spatiotemporal object information under test conditions where the cognitive load was reduced to a minimum – i.e. in an event monitoring design.

However, in a recent series of studies, Krøjgaard (2007) devised such a design. Infants 9.5, 8.0, and 6.0 months of age were presented to a 'rotating screen design' in which they witnessed a basic scenario where a cut-open cylinder rotated around stationary objects (see Fig. 4).

The infants were tested in one of two different conditions: An Object Chance Condition and an Object Disappearance Condition. Following habituation, the infants were presented to expected and un-expected test events. While the expected test events were the same for infants in both conditions, the un-expected test events differed: In the (un-expected) *Object Change Condition,* one of the objects had appearantly changed appearance (from a Brio Clown to a Lego Man or *vice versa*) every time the cut-open cylinder revealed the contents. Thus, the un-expected Object Chance event involved a *featural* object change.

In the (un-expected) *Object Disappearance Condition,* the target object disappeared and reappeared on each two consecutive turns by the cut-open cylinder, that is, a *spatiotemporal* violation.

By means of the VOE paradigm the looking time of the infants was recorded and subsequently analysed. The results revealed that while the oldest (9.5-month-old) infants in both test conditions reacted with surprise when watching the un-expected test events as opposed to the expected test events, the results from the younger group of infants were different: Whereas the 8.0-, as well as, the 6.5-month-old infants in the Object

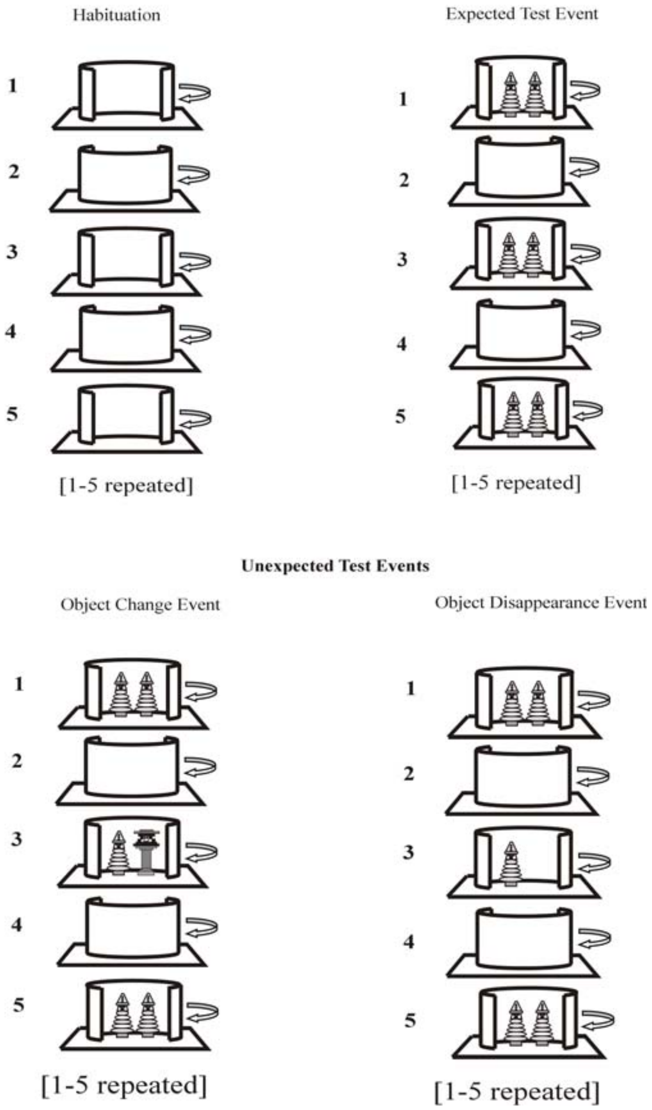


Figure 4. Schematic representation of the habituation and test events applied in Krøjgaard (2007).

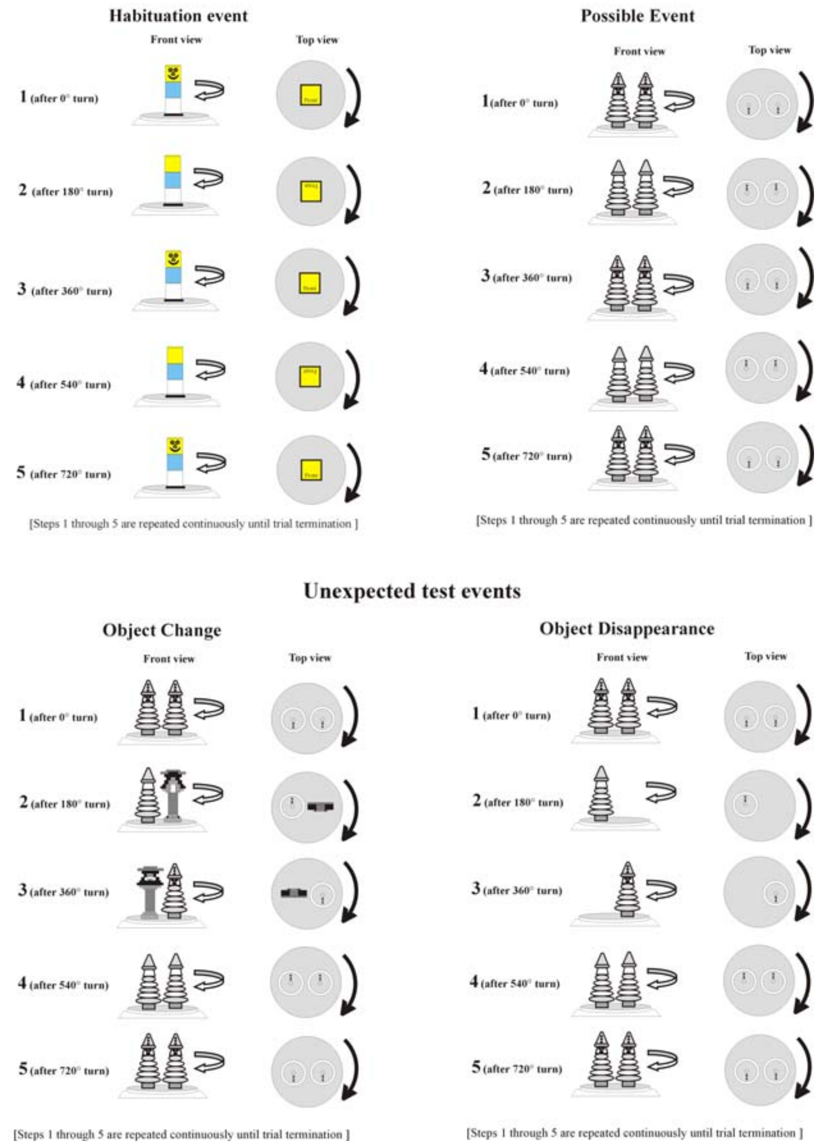
Change Condition *failed* to individuate the objects, their same-aged peers in the Object Disappearance Condition *succeeded* (Krøjgaard, 2007).

Note, given the fact that all test events in the design employed by Krøjgaard (2007) unfolded in one on-going sequence, the design qualifies to the group of simpler and less cognitively demanding event monitoring designs (cf. Wilcox & Baillargeon, 1998a). Consequently, the immediate interpretation of the results derived from Krøjgaard's (2007) study may be that spatiotemporal information seems to be generally superior to featural information when infants attempt to individuate objects.

However, such a bold conclusion does not seem warranted. Even though the rotating screen design employed by Krøjgaard (2007) qualifies as the less demanding event monitoring kind of design, the negative results obtained by the younger infants in the Object Change Condition appear somewhat surprising, considering the evidence derived from the wide-screen/narrow-screen design by Wilcox and Baillargeon (1998a, 1998b) where infants down to 4.5 months of age succeeded in individuating objects.

How can this divergence in results be accounted for? At least two obvious differences between the rotating screen design and the wide-screen/narrow-screen design may explain why the infants in the rotating screen design were less successful in individuating objects than their peers who participated in the wide-screen/narrow-screen design: First, while the objects in the wide-screen/narrow-screen design moved, the objects in the rotating screen design remained stationary. Second, while the objects in the wide-screen/narrow-screen design were occluded for approximately 1 second out of each 5 seconds sequence, the objects in the rotating screen design were occluded for approximately 2.2 seconds out of each 4 seconds period. Thus, although both designs can be said to belong to the same category of relatively simple (event monitoring) designs, there is reason to believe that the rotating screen design, all things equal, is more cognitively demanding than the wide-screen/narrow-screen design (Krøjgaard, 2007).

In another very recent experiment Krøjgaard (in press) attempted to eliminate the potentially negative influence of using (a) stationary objects, and (b) long occlusion times (see Fig. 5).



Habituation event

[Steps 1 through 5 are repeated continuously until trial termination]

Possible Event

[Steps 1 through 5 are repeated continuously until trial termination]

Unexpected test events

Object Change

[Steps 1 through 5 are repeated continuously until trial termination]

Object Disappearance

[Steps 1 through 5 are repeated continuously until trial termination]

Figure 5. Schematic representation of the habituation and test trials applied in Krøjgaard (in press).

Using a similar setup, the rotating screen was replaced by a rotating platform on which the objects could be placed and hereby move. As displayed in Fig. 5 the un-expected events were carried out without having the objects occluded at all. This was made possible by using a mirror arrangement in which two synchronically rotating platforms were in play although everything from the point of view of the spectator appeared to take place straight ahead (see Fig. 6).

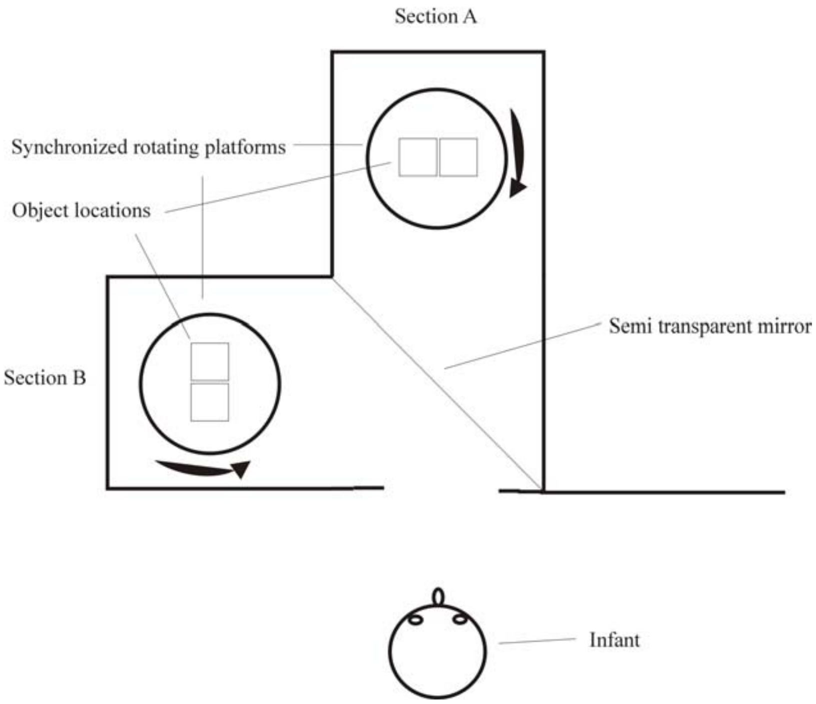


Figure 6. Schematic representation of the mirror arrangement. By instantaneously turning on and turning off the lights in Sections A and B respectively, the viewer's focus can be changed from A to B (and vice versa), although the viewer experiences the event as taking place in *one* location.

Thus, the mirror arrangement made it possible to reduce the occlusion time to nil, and hereby entirely eliminate the cognitive load induced by momentary concealment of the objects (Krøjgaard, in press).

Two structurally identical experiments with 8.0-, and 6.5-month-old infants were conducted by means of the 'rotating platform design'. The results revealed that the infants in both test conditions managed to individuate the objects regard~~s~~less of which condition they were allocated. Thus, by using a more dynamic scenario with moving objects and by eliminating the eventual negative effect of occlusion, the infants were indeed able to individuate objects successfully regard~~s~~less of whether they primarily had to rely on featural or spatiotemporal information (Krøjgaard, in press).

To summarize, there is still no definite conclusion regarding the question of whether spatiotemporal information is generally superior to featural information when infants attempt to individuate objects (for opposing views, see e.g., Xu, 1999, 2003 and Needham & Baillargeon, 2000). More research is simply needed. However, there seems to be no doubt that infants are capable of individuating objects, and that spatiotemporal information does play an important role when doing so.

Infant Research: Summary

What can be learnt from research on object individuation in infancy? First of all, the research outlined here provides compelling evidence that the ability to single out and track specific objects through space and time is not restricted to adults. On the contrary, some of the basic building blocks constituting such an ability seem to be quite evolved even among young infants – at least here-and-now. Thus, even early in their first year of life, infants pay attention to featural, as well as, spatiotemporal information when attempting to track objects in space and time – the two kinds of information that also play prominent roles when adults track objects. We have also seen evidence that when in doubt, spatiotemporal information seems to override featural information. Hence, spatiotemporal information may very well be even more basic than featural information. Accordingly, and returning to our fictitious young student trying to find his bicycle outside the department, it may not be trivial at all that our immediate (but insufficient) explanation is likely to be one stating that our student’s search will be based solely on featural information. We may simply have forgotten the extent to which spatiotemporal information provides the ground on which featural information stands out. This is one of the reasons why it remains an important question to study the timing of infants’ use of featural and spatiotemporal information respectively when attempting to individuate objects, because it helps us outline the ontogenetic emergence of these core abilities. One might speculate that if researchers of cognitive psychology had started out studying infants, and not adults, they may never have believed that one could safely neglect spatiotemporal information.

Object Individuation in Non-Human Primates

When researchers attempt to demarcate the specifically human, several important tools are available. In recent years evolutionary psychology has become one of the most rapidly growing approaches in this respect (e.g., Katzenelson, 2007). And studying our closest relatives is an obvious window in pursuing such a goal (Byrne, 1995; Tomasello & Call, 1997). Thus, one of the central questions entailing considerations regarding the human ability to single out specific objects in space and time is whether our closest relatives (e.g. non-human primates) possess competencies similar to the ones outlined above.

Until recently there seemed to be consensus that non-human primates were somewhat inferior when considering their ability to identify objects and make categorizations. For example, in their comprehensive review of the literature, Tomasello and Call (1997) wrote the following a decade ago: Few animal species have any skills at sorting objects into groups the way that human infants and children do with such facility during the preschool years, and the ecological relevance of such skills for most species is not easy to determine. Primates have some relevant skills (combining their skills of categorizations and manipulation) but they seem to be extremely limited compared with humans. (183-184).

Although the abilities in non-human primates are indeed inferior to especially adult human beings (see below), the results from a few recent studies actually suggest, that some of the apes may seem capable of individuating objects:

Santos and her colleagues (Santos, Sulkowsky, Spaepen & Hauser, 2002; Flombaum, Kundey, Santos & Scholl, 2004) have recently pioneered in conducting studies on object individuation in rhesus macaques (*Macaca mulatta*). For example, Santos and her collaborators (Santos et al., 2002) used a modified version of the manual search paradigm originally devised for human infants (e.g., Van de Walle et al., 2000). Rhesus macaques were shown food objects (fruits) being placed in a closed box filled with leaves. Subsequently, they were allowed to search for the food items. However, due to a trick the rhesus macaques found their hidden food items to have undergone changes in either kind (i.e. featural violation) or number (i.e. spatiotemporal violation). Search time was recorded, and the results indicated that the rhesus macaques searched significantly longer when either the kind or the number of the appearing objects had been changed as opposed to controls (Santos et al., 2002). Thus, analogue to human infants, rhesus macaques seem capable of individuating objects by featural, as well as, by spatiotemporal means.

In another experiment Flombaum et al. (2004) showed that members of the rhesus macaques displayed the ‘tunnel effect’: When watching an event in which an object moved behind an occluder and subsequently reappeared on the other side of the occluder as a differently looking object, the apes reacted (based on their reaching performance) as if only a *single* object was involved in the event (cf. Fig. 1; see also Santos, 2004). This reaction from rhesus macaques resembles the interpretation reported from human adults presented to similar scenarios (Michotte, 1962; Xu, Carey & Quint, 2004).

Thus, resembling some of the findings from human infants, a limited set of studies have shown that rhesus macaques are able to individuate objects successfully by means of featural or spatiotemporal information. Provided that additional evidence will converge with the above recent findings, it seems to be the case that at least *some* of the basic building blocks required for being able to single out and track specific objects through space and time, here-and-now, are indeed manifest in some of our ancestors.

Tracking Objects: Uniquely Human Applications

As the evidence above shows, there is reason to believe that aspects of the ability to single out and track specific objects through space and time may be present in a few non-human primates too (i.e. rhesus macaques). Hence, as such, the ability to single out and track specific objects through space and limited durations of time cannot be said to be a uniquely human competence. Nevertheless, as I shall argue, human beings seem able to exploit this ability to a level far beyond what other species are capable of. In the following, I will direct attention to two specific areas where this seems to be the case. First, we will take a look at how the ability to single out and track specific objects through space and time appears to be a necessary precondition when infants and young children begin to form concepts and learn words. Second, I will argue that such ability is necessary to conceive of man-made artefacts and culture in general.

Concept Formation

Through the first years of the ontogenesis, the vocabulary of children expands with impressive speed. Children usually say their first word around 12-13 months of age, and by the age of 6 years they typically have a vocabulary consisting of approximately 10,000 words, implying that children between the ages of 1 and 6 on average have to learn more than 5 new words daily (Bloom, 1998). One obvious way of learning nouns is what has been coined ‘the original word game’ (Brown, 1958), in which an adult directs a child’s attention to a specific object (e.g., a butterfly) for example by pointing while saying: “This is a butterfly!” In order actually to learn the new word in such a context, a range of necessary conditions will of course have to be fulfilled. I will not go through all these (e.g., being able to understand the intention of the adult, hearing the concept, remembering the concept, etc.), but would just like to draw attention to one necessary prerequisite that often seems to be overlooked or neglected when considering concept formation or word learning – often at the expense of ‘language games’ (Wittgenstein, 1958). As the reader may already have guessed, I am referring to the ability to single out and track specific objects. However, Spelke displays the relevance very clearly when she writes:

> There is a core conception, *physical object*, of which sortal objects such as "table" and "horse" are specific examples, and this conception does the major work of singling out physical bodies and tracing them through time. […] There must be some way of apprehending books and following them through time that does not itself depend on an already developed sortal concept. It is reasonable to suppose that a general conception of *physical object* fulfils this function (Spelke, 1988, p. 231, italics by author).

Spelke believes further that such *core knowledge* regarding physical objects is hard-wired from birth (Spelke, 1994). Note, however, that the argument that word learning should rely on the ability to single out and track specific physical objects in space and time is not contingent upon the nativist claim endorsed by Spelke. Hence, it is by no means surprising that others have reached the same conclusion about the importance of being able to single out objects as a precondition for concept formation (Kingo, in press; Mandler, 1997; Nelson, 1974).

Understanding Man-Made Artefacts

By introducing the term *affordance*, Gibson (1979) tried from an ecological perspective to show how meaning to a large extent already was ‘out there’ in the relation between the subject and the object. The theory of affordances may provide a satisfactory framework for understanding what each single object may offer a given subject. However, one might argue that some affordances are more salient than others and that some affordances ultimately may not be out there for simple information pick-up without *a priori* knowledge of the object in question. For example, while a hammer may easily afford hammering for a human being (among many other affordances, of course), it does not seem obvious, at least not to me, that some of the powerful affordance related to the computer, I am currently writing on - e.g. storage of information and sending emails - should be available and ready in the visual array just to be picked-up by a subject that never seen or heard of a computer before. Such ‘affordances’ seem to require earlier acquired knowledge in order to be perceived effectively.

Another potential criticism regarding the Gibsonian approach to the perception of meaning is the inability to distinguish between the meaning of natural objects, on the one hand, and man-made objects or cultural artefacts, on the other. While both natural objects (e.g. stones) and man-made objects (e.g. stone axes) offer a large number of different affordances, only the man-made objects are *intended* for *specific* purposes (Bærentsen & Trettvik, 2002; Mammen, 1986; Tomasello, 1999). This important difference between natural and man-made objects seems difficult to grasp within a Gibsonian framework.

Consider, for instance the following thought experiment:[3] Imagine we have two identically looking pieces of flint stone, both in the shape of an arrowhead. One of the stones (stone A) is a natural result of a storm in which a giant tree hit a larger piece of flint stone, causing the stone to break into two pieces of which one of the pieces by coincidence got the shape of a perfect arrowhead. The other stone (B) is the result of several hours of meticulous work by a competent Stone Age man. Since the two ‘arrowheads’ A and B are completely identical from a featural point of view, it seems impossible to distinguish between them armed with a Gibsonian framework. However, even if we cannot tell the two ‘arrowheads’ apart, human beings are perfectly capable of *understanding* and *acknowledging* the difference between the one that was made by a fortunate event in nature (stone A) and the one resulting from intentional work by a skilful Stone Age man (stone B). If human beings were ignorant of such differences, there would be no point in exhibiting fragments of old Greek vases, ancient coins or original stone arrowheads in museums; no one would have reasons to be annoyed if original pieces of art were

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[3] The thought experiment is inspired by an equivalent one given by Jens Mammen (personal communication).

duplicated (cf. Mammen, 1993; Krøjgaard, 1999a) - and *The Little Prince* would have no reason to bother about his unique and precious rose.

However, adult human beings are indeed sensitive to such differences. One might ask what competencies allow human beings to understand clearly the differences between stones A and B or the importance of museum exhibits (e.g. fragments of an ancient vase) of which the present affordances are rather limited? Mammen (1996) has convincingly argued that the ability to single out and track specific objects through space and time is an important prerequisite for such ability. However, although necessary, such ability may not be *sufficient*. Given that rhesus macaques - just like human infants - may be endowed with the basic abilities necessary in order to individuate objects, as seen earlier in this paper, one might speculate what adult human beings *add* to this ability when they demonstrate such elaborate~~d~~ understanding of cultural artefacts, as mentioned above. I will tentatively suggest that one important competence that adult human beings may apply when grasping the ontology of man-made artefacts is their ability to *abstract* the spatiotemporal threads related to specific objects and implement these in new domains or contexts. Note how following the spatiotemporal path of a given object (e.g., an arrowhead) here-and-now is simply insufficient to understand the historical thread of the thousands-of-years-old piece of flint stone. Without the ability to abstract and envision the history of the arrowhead abstracted from its current appearance, the difference between stones A and B would be incomprehensible.

I believe that several pieces of evidence implicitly support the claim proposed above: Tool use in human beings is far less bound to specific contexts than it is the case for non-human primates (Byrne, 1995; Tomasello & Call, 1997). Intentional teaching to conspecifics is far more developed in human beings than in non-human primates (Byrne, 1995; Tomasello & Call, 1997). One-trial learning is much more common in human beings than in non-human primates (cf. Krøjgaard, 2006). Program-level imitation is far more prominent in human beings than in non-human primates (Byrne, 1995). While these well-established differences between human beings and non-human primates diverge strongly with regard to sociality, purpose, and application, they all *share* the feature of relying on the ability to *abstract* certain aspects of a given situation and subsequently apply the abstracted material to another domain or context. I do not claim that this is the only competence relevant for understanding man-made artefacts, but I do claim that such ability plays a significant role. In short, the argument is that if one was unable to single out and track specific objects through space and time and subsequently abstract this information from one domain into another, then it seems very difficult, if not impossible, to follow stone B or vase fragments through space and time on a larger scale. Furthermore, without such ability man-made objects and consequently culture simply seems beyond comprehension. Thus, while *sharing* may be a uniquely human feature as argued by Tomasello and colleagues (Tomasello, Carpenter, Call, Behne & Moll, 2005), I believe that specific *cognitive* skills (i.e. the ability to abstract from one domain or context into another) need to be added to the unique human repertoire. Social-cognitive prerequisites appear to be insufficient as the examples from the present paper should hopefully illustrate.

Concluding Remarks

Here I have attempted to pursue the origin of the ability to single out and track specific objects through space and time. The results from a substantial amount of experimental studies indicate that basic aspects of such ability (e.g. object individuation) are already present and operative, at least to some extent, in young infants. Meanwhile, a few recent studies have revealed that similar basic aspects of such ability may very well also be present in at least one species of non-human primates, that is, rhesus macaques. Thus, while adult human beings may indeed employ the ability to single out and track specific objects through space and time when understanding man-made artefacts and culture in general, they must do more than track objects here-and-now in order to produce the advanced level of elaborated understanding of culture that characterises adult human beings, but not non-human primates. I have tentatively proposed, that the added tool may be the ability to *abstract* the spatiotemporal threads that constitute the tracking of objects. Such claim cannot be proven, but only falsified. If, for instance, evidence that indicate that some non-human primate is capable of abstracting spatiotemporal threads related to objects from one domain or context into another is obtained, then the claim will be falsified. Provided that the ‘abstraction hypothesis’ proposed here is valid, we would also need to consider *when* and *how* it comes into play through the ontogenesis of human beings.

Another important area for further research is comparative psychology. Given that the amount of evidence on object individuation in non-human primates is limited, we simply need to conduct more comparative studies on these and related issues.

Attempting to produce relevant pieces to the large and complex jigsaw-puzzle of specifying the eternally prominent question regarding who we are as human beings, evolutionary psychology has beyond any doubt proven an important and worthwhile approach. Throughout this paper I have tried to demonstrate that investigating basic human competencies as they evolve early in the ontogenesis is another powerful tool. If we are to succeed in uncovering what is uniquely human we may need to a larger degree than hitherto has been the norm to *combine* these two approaches.

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CHAPTER SIX

WHY EVOLUTIONARY AND DEVELOPMENTAL COGNITIVE PSYCHOLOGY? THE IMPORTANCE OF NON-HUMAN PRIMATES & HUMAN INFANTS FOR UNDERSTANDING ADULT USE OF MODERN COMPUTERIZED TECHNOLOGY

RUNE NØRAGER

Abstract: State of the art human technologies like cell phones and computers have become indispensable to many in our daily lives. To just as many, however, the uses of such modern computerized technological devices also pose daily challenges. Rigorous research in primate tool use has provided numerous insights that can be put to use to understand how this forefront of human technology can be made easier and more intuitive to use and thereby assist in overcoming these challenges. Based on evolutionary and developmental cognitive psychology, it is identified that:

1) Modern computerized technology lacks sufficient support for the basic dynamics that characterise tool use in primates.

2) These basic dynamics are supported by corresponding cognitive resources, the nature of which is well studied in both animal cognitive research and infant developmental cognitive research.

Based upon this, it is hypothesized that these functional dynamics can be implemented back into computerized technology and hereby support basic cognitive abilities in humans. Preliminary results, which support this approach, are reported from experimental studies derived from this theoretical framework.

Background: Framing the Problem

As a scientist in cognitive psychology and a technology consultant, I often experience that people, in general and professionals like industrial designers and software engineers, are puzzled as to what role psychology can possible play in the development of technology. My argument is usually that with intricate knowledge about how humans perceive, think and act, we are able to design technology that matches these skills in the best possible way. Much like the ergonomics of a chair requires knowledge about the human biomechanical physiology, so too do cognitive ergonomics require knowledge about cognitive dynamics. In this article I shall pursue this argument in a broader scope, namely by following a direct line from cognitive research of non-human primates over infant cognitive development and adult cognition to the design and development of modern computerized technology. Paradoxically, it is the basic cognitive ergonomics of basic human tool use that lend themselves very well to be studied in its pure form in primates and infants that will provide some novel insights of how to design advanced human computerized tools.

It is important to stress that although much attention is devoted to technology in the article, and especially computerized technology, this is motivated by the unique possibilities captured hereby to investigate both theoretically and experimentally key aspects of what is particularly human in a novel way with human adults. More specifically, computerized technology allows us in experimental conditions to isolate and manipulate key variables of human cognition that are also in focus in non-human primate research and human infant developmental research. In summary, the applied field of human-computer interaction has the potential to provide research in animal cognition with an additional string to play on in the quest to isolate the particularly human aspect and how it unfolds under various circumstances.

Tools: Causalfunctional Objects, Purposeful Artefacts and Computerized Technology

The evolution of human tool use can be described in various ways depending on which characteristics of the tools and their use one focuses on. From a psychological cognitive perspective, the evolution of human tool use can be described as a function of the cognitive complexity reflected in the tools. Such a description starts with the transition from basic stone tools, that functioned as crude amplifications of natural capabilities, over composite tools like the axe and bow, where knowledge of mechanical forces make it possible to transform these forces and modulate them. The next step in this progression is the addition of externally powered tools that finally have cybernetic dynamics of automatic control and regulation incorporated, like the fly-ball governor in steam engines[1]. In this paper, however, a somewhat different distinction of technological evolution will be made that is motivated by how primate tool use can inform human computerized tool use. The distinction used could be considered a psychological cultural-historical equivalent to the pure cognitive psychological lineage outlined briefly above. In this psychological cultural-historical optic, three categories or distinctions about tools are motivated. These will briefly be outlined and then discussed in light of current research.

First, some tools are considered basic objects with purely causalfunctional properties in relation to other objects. They are not tools as such but merely temporary means to an end. All objects in this category of tools can be used as means to a specific end, as long as they share the relevant causalfunctional properties. A rock can be used for a number of purposes such as a weight, a crude hammer, a doorstopper, etc. Tools in this category are therefore only constrained by their inherent physical causalfunctional properties. Objects thus only momentarily become tools as a consequence of the immediate needs of the primate or human who picks them up.

The *second* category consists of purposeful tools, i.e., tools that in a social and cultural context have been developed to realise and attain certain goals. This class of tools can be argued to be distinctly human since it requires a social and culturally shared tool practice (Bærentsen, 1989; Klix, 1980). Furthermore, this aspect of tools is heavily integrated with the use of language that functions as a categorical marker for the intentionality imbedded in these tools (Jaswal, 2006; Kemler Nelson, Russell, Duke & Jones 2000). Although a tool from a purely causalfunctional perspective might serve various different uses, they are meant for very specific purposes that constitute a subset of the causalfunctional possibilities and sometimes only a singular use. This relation plays out at the dinner table when children are carefully instructed that the cup is used for drinking and not for any other purposes, although initially the child constantly challenges this narrow cultural use. The linguistic cultural aspect of tools thus narrows down the use of tools as a subcategory of their causalfunctional possible use. Although different objects may be used to achieve the same goal, they are typically not due to the constraints of cultural labels and practices.

The *third* category consists of computerized technology. It distinguishes itself from the other two categories by its lack of a functional material, physical substance (Bærentsen, 2000). The causalfunctional properties of a cell phone’s physical form do not in any way correspond to its intentional functional design purpose (ibid.). The functionally intended design purpose of computerized technology can therefore only be grasped by the functional logic of the software code embedded in it. The screen of the cell phone and the buttons on the front give a hint at this functionality from a symbolic discourse but usually there is more than meets the eye. This is why we need elaborate manuals to inform us about how to operate and access the hidden functionality imbedded in the software. The functionality designed into software codes in programmed technology therefore distinguishes itself from the functionality imbedded in physical artefacts in that the realm of intended use and possible use are the same (Bærentsen & Trettvik, 2002). As most parents will know, the proper canonical use of a cup can be negotiated and relativised. i.e., although the cultural linguistic dimension imposes constraints on the use of such artefacts, these constraints can be broken. In computerized functionality, however, there is a one to one correspondence between the intended use and the possible scope of use (Bærentsen & Trettvik, 2002), i.e., there is no other meaningful use than the culturally intended use designed into the software[2].

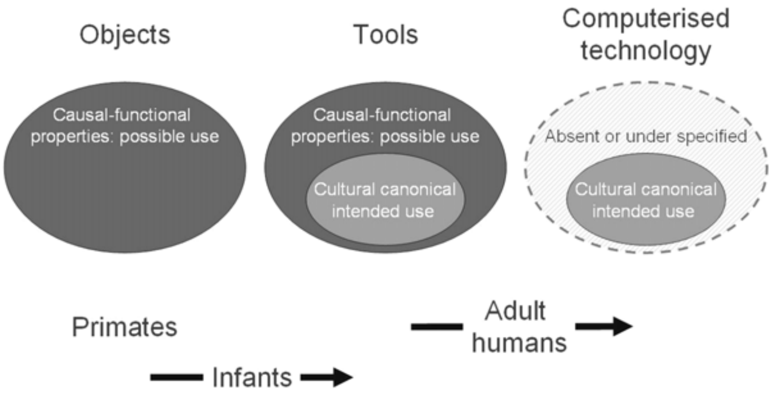


Figure 1. Cultural-historical distinction of tool use evolution

To qualify this triadic segmentation of tool use three lines of research will be outlined:

1. Primates’ conceptual understanding of objects and their causal-functional properties.
2. Human infants´ understanding of tool use and rational agents’ tool use.
3. Neuropsychological studies of tool use and understanding in brain injured patients.

The goal of this theoretical analysis of current research findings in comparative psychology, infant cognitive development and neuropsychology is tentatively to outline the dynamics of the interplay between the causal-functional and cultural dimension of tool use, i.e. the first and second tool category. Even though many questions are still unanswered and debated in these lines of research, there is enough established consensus to address computerized technology from this combined primate and infant developmental approach.

[ad. 1] For a more detailed review of this lineage I refer the reader to Bærentsen (1989) and Nørager (2004).
[ad. 2] Colleagues from computer science typically contest this sharp distinction by saying that software functions can also be negotiated. While this is true to some degree for skilled software professionals like hackers, this is still a far cry from qualitative new uses like those invented by children with the cup at the dinner table.

Primates’ Understanding of Objects and Causal-Functional Properties

In a number of experiments it has been demonstrated that primates have a fundamental repertoire of representational systems that constrains the behaviour of objects in space and time based on spatio-temporal information (Weiss & Santos, 2006). Although there are limitations to these abilities, such as interactions between objects when they are occluded (Flombaum, 2004), it does provide primates with the basic ability to predict how objects behave in time and space, i.e., their causalfunctional properties. This is a fundamental basis for productive tool use and in studies by Hauser (1997), Santos et. al. (2003) and Evans & Westergaard (2004), it has been found that primates can directly perceive the relevant causalfunctional properties of tools and base their choice of tools on the most optimal relation between their end goal and the causalfunctional properties of the tool. In these studies *functionally* irrelevant properties like colour, texture and pattern were ignored by the primates (ibid.). Basic causalfunctional representational skills have also been documented in non-primates like the Caledonian crow (Weir & Kacelnik, 2006). The ability to represent objects over time and space and their causalfunctional relations therefore seems to be a basic ability in a range of animals that does not seem to require linguistic nor advanced intellectual reasoning skills reserved only for humans (Weiss & Santos, 2006).

Tools as Cultural Artefacts: The Design Stance

Human tools are special due to the lasting intentionality that they represent. This is what Daniel Dennett calls the design stance of tools (Dennett, 1987). Studies have demonstrated that when a human actor uses a tool to an end that involves surplus movements that have no direct causal function, like tapping on the side of a box with a stick, these are ignored by chimpanzees but closely mimicked by children of age 3 to 4 (Horner & Whiten, 2005). This difference can be taken to indicate that primates are only sensitive to the causalfunctional properties of the scene, whereas children are also sensitive to the properties of the cultural dimension of the scene (Horner & Whiten, 2005; Casler & Keleman, 2007). The reason for the primates' lack of sensitivity to cultural norms beyond pure causalfunctional aspects might be due to differences in human and primate cultural schemes. However, studies by Whiten et. al. (2005) suggest that primates are indeed capable of distinguishing between different cultural tool use approaches as long as these distinguish themselves with regard to purely causalfunctional properties. This can be taken to account for how primates have schemes similar to humans that allow them to represent qualitatively different approaches to the same problem.

It is important to realise that in such re-enactment experiments, the children are indeed sensitive to the *intentionality of the actor* and not merely copying the action sequences at the programme level. This has been demonstrated in studies by Meltzoff (1995) where infants as young as 18 months would not blindly reinact the actual (failed) behaviour of an actor but recognized and re-enacted the intended goal-directed behaviour. Young children are thus sensitive to the intended goal of the actor and not merely making a programme level imitation of the action sequences. Furthermore, studies by Whiten et. al. (2006) have demonstrated that threeyearold children appreciate the hierarchical structure of action sequences and how these can be flexibly interrelated.

This sensitivity to the cultural design stance of tools coincides with the early appropriation of linguistic skills. In a study by Gergely, Bekkering, and Király (2002) it was investigated whether 14 months old children would readily imitate an adult´s goal directed activity under two different constraints. In one condition children would watch an adult actor wrapped in a blanket, with the hands inaccessible, turn on a lamp placed on the table with the head. In the other condition the actor would also wear a blanket but have the hands placed next to the lamp, while still using the head to turn on the lamp. The use of the head instead of the hands was thus either constrained by physical conditions or by choice of the actor alone.

Of the children who witnessed the scene where the actor´s hands where occupied, a majority would instead use the hands to switch on the lamp. In the condition where the actor´s hands were free, a majority of the infants would copy the actions of the actor and switch the lamp on with their head as well.

In the interpretation of the results by Gergely et. al. (2002) children are on the one side subject to the same emulation as primates, opting for a more direct approach using the hands to achieve the same goal as the actor. On the other side, in the absence of any physical constraints, children seem able to evaluate the scene and appreciate the rationality of the actor and hereby go beyond mere emulation. At three to four years of age when language is well mastered, children are also sensitive to the excess cultural aspects of tool use that have no apparent causalfunctional meaning (Horner & Whiten, 2005).

The cultural canonical design stance can be seen as comparative to the causalfunctional constraints by further limiting what objects can and should be used for by introducing an “ought to” or “should” dimension nested inside the realm of possible “can” uses (Trettvik, 2006). Sensitivity to social information about the canonically intended use of artefacts is very outspoken in young children and helps them to quickly form enduring function based categories about canonical uses of tools (Casler & Keleman, 2005, 2007). The constraints of the cultural dimension are further documented in that the names children extend to objects are based on their shared causalfunctional use rather than their overall featural similarity (Casler & Keleman, 2007).

There are, however, limitations to the constraints of the cultural design dimension. Studies by Asher & Kemler Nelson (2007) with 3-4 year olds demonstrated that uses of tools that seemed to oppose their inherent causalfunctional constraints, i.e. implausible use, would generate more inquiring questions about such tools’ functionality, as opposed to when use of the tools was causalfunctionally plausible. Such findings can be taken to account for that at the age of 3-4 years, excess cultural movements in the use of tools are considered acceptable as long as these fall inside the constraints of the causalfunctional properties. Cultural norms can thus narrow the causalfunctional uses of objects and tools but not to the extreme.

Although primates do not seem to be sensitive to cultural excess tool use dynamics, studies by Whiten, Flynn, Brown, and Lee (2005) have documented what could be described as a primordial sensitivity to cultural tool use norms. In their studies two strategies for freeing a nut from a contraption was introduced to two groups of chimpanzees by means of a high ranking female that had observed a human instructor perform the action. Both strategies were viable and functionally optimal in their own right from a causalfunctional perspective and did not involve excess cultural movements. Whiten et. al. (2005) reported a conformity bias in chimpanzees that had discovered both strategies towards using the predominant strategy of their companions.

Broad empirical findings thus support that infants and primates have advanced representational skills that allow them to appreciate causalfunctional relations between objects. Sensitivity to cultural norms of tool use that cannot be derived from the objective physical constraints alone seems however, to be beyond primates and preverbal infants. Only in young children with verbal abilities do we find sensitivity to unique human culturally constrained tool use dynamics.

From Objects to Cultural Tools in Infants and Adults

Human tool use is combined both of causalfunctional properties and a canonical design stance (Hauser, 1997) – then "can" and "should" dimension. The transition from handling and seeing artefacts not only as sensory-motor objects, but also starting to know of their intended cultural canonical use is profoundly documented in the scale error phenomenon, which has been formally investigated in recent years (Deloache et. al., 2004; Ware et. al., 2006). In scale error situations 18 to 30-months old children have the possibility to play with toys such as a car, a slide or a couch that are life-size, i.e., scaled to their bodily dimensions. Research assistants will encourage the children to slide down the slide, sit inside the car and on the couch. Later in the experiment small miniature toy replicas of the same objects are introduced into the play. The scale error phenomenon arises when the children try to use these miniature toys in the same fashion as the life-size toys. They will, for example, try to fit their feet inside a toy car and slide down a slide both of which are so small they fit on the palm of their hands. It is very clear that nothing is wrong with their sensory-motor functions since their object manipulation skills are precise and adequate when they grasp and manipulate the toy replicas. In contrast, their intentional goal is not adequately adjusted to the toy replica. They try to sit on the small couch and even try to enter the small car that does not even allow their foot to fit inside. The children will put considerable effort into realising their cultural knowledge driven canonical use of the objects with the small copies and consequently, look very puzzled and displeased when they fail to attain this goal. The toy replicas seem to activate cultural canonical use representations of the artefacts and force a knowledge driven activity programme onto an object that does not correspond causalfunctionally to it. Whereas these studies involved scale errors in young children and objects related to their own body, recent scale errors have also been investigated in relation to scale errors between two objects in the world such as a doll and a toy bed (Ware et. al., 2006). It thus seems that scale error is a general phenomenon that occurs in children's interaction with toys, i.e. cultural artefacts, during their first years of language use.

The scale error is explained as a neurological perception-action dissociation in early life that later in adults becomes fully integrated (DeLoache et. al., 2004, Ware et. al. 2006). Similar perception-action dissociation are also documented in adult neurological patients where brain injuries selectively can damage patients' conceptual understanding of what tools are for while they retain the ability to handle the tool skilfully. Comparatively, other patients are unable to handle tools in a meaningful way but are still able to identify the artefacts, name them, and describe their function (Daprati & Sirigu, 2006; Goodale & Milner, 2006; Johnson-Frey, 2004). These complimentary neurological systems have become known as the "what" versus "where" systems (ibid.). The "what" system supports conscious naming and identification of artefacts and is believed to be a more recent evolvement than the evolutionary older "where" system that supports the sensory-motor handling of objects (Goodale & Milner, 2006; Velichkovsky, 1990). This distinction resembles the causalfunctional "can" dimension and the cultural intentional "should" dimension.

Theoretically, this dual aspect of artefacts has been analysed inside the Activity Theory framework as an extension of James Gibson's concept of affordance that mainly focused on natural biological sensory-motor affordances (Bærentsen & Trettvik, 2002). This has traditionally invoked a number of problems since Gibson's theoretical work was hard to conceptualise in relation to cultural artefacts. Bærentsen & Trettvik (2002) thus posit the need for a dual understanding of affordances that both have a biological evolutionary background and a cultural historical background. Biological evolutionary founded affordances are called adaptive operations since they are evolutionary adaptations to the physical world (ibid.). Affordances that are cultural-historical founded are called conscious operations since they are seated in the individual's conscious interaction and knowledge about cultural specific norms of the use of artefacts (ibid.). Such affordances are not directly perceivable in the objective physical properties but manifest themselves as extra material social dynamics that unfold themselves over time.

When scale errors are appreciated inside this cultural-historical tool use dimension, it follows that scale errors are not merely a dissociation between cognitive functions but between basic sensory-motor object handling skills and their cultural-historical meaning. The scale error dissociation between the causalfunctional properties of an object and the uniquely human cultural design stance can therefore be hypothesized not to occur in animals. Indeed from an evolutionary perspective, it would be highly maladaptive for animals to be subject to scale errors. Scale errors are instead to be understood as the epiphenomenon of infants' transition into a world not only of material objects but also of extra material cultural norms.

Human tool use can thus be considered as a unique cultural dimension that furtherconstrains the natural causalfunctional properties of objects. The unique properties of computerized technology can therefore be unfolded in a cultural historical perspective as a kind of tool that is only constrained by the cultural dimension but not by the physical causal-functional dimension. This viewpoint is further developed in a deeper analysis of the historical development of computerized technology.

Computerized Technology

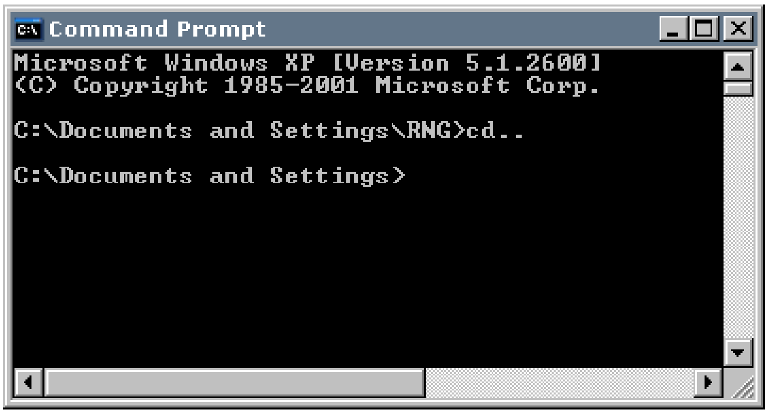
It is the central argument of this article that modern computerized technology is functionally separated or abstracted from the material and physical basis that characterises material tools. Even though a computerized tool such as a cell phone or a video recorder are tangible physical objects, their functional meaning, i.e., what they essentially are and do as tools, is primarily constituted by the software code that controls and regulates the relations between the physical buttons and the graphical representations we see on the menu screens, i.e. how the tool ultimately behaves. This makes computerized technology, no matter what shape or form it comes in, a distinct kind of technology quantitatively different from all other technologies and tools that in their way of functioning are subject to the constraints of the physical world. The software codes used to create computerized technology are formalised symbolic languages that define logical procedures. Software is thus not constrained by the physical laws whereby it is possible to violate these laws as it happens when an object on a computer screen suddenly disappears (Bærentsen, 2000). In this way the discourse for how to understand and conceptualise disembodied software as a language is principally in the domain of structural semantics (Johnson, 1987). Computerized technology in a functional sense can thus be seen as a reflection of unique, complex human linguistic capabilities rather than basic tool making skills based on causalfunctional manipulations.

The paradox of computerized technology is that ever since its advent in the early fifties, as the epiphany of human technological development, there has been a gradual movement towards more and more support for more basic human cognitive abilities in the way we interact with such technology – for example by opening it up to out causalfunctional sensory-motor skills by making it more tangible (Dourish, 2004). It is this recapitulation that now calls for evolutionary and developmental psychology to provide novel insights into how this process might continue and existing achievements advance further.

Symbolic Tools: From Command Lines to Direct Manipulations

In the earliest days of computerized technology, interaction with computers was a painstaking procedure that required computer scientists who essentially had to manually construct a new computer for each new task. With the advent of more generic and automatic instruction and input routines, it became possible to execute simple programmes that the scientists did not have to create from scratch each time. Despite the complexity even at this level, it did however, facilitate the spread of computers and computerized technology to a broader scope of uses – though still heavily framed inside scientific and military purposes. While modern computerized technology still rests on the same logical foundation as the early computers, the ways in which we interact with these devices have progressed dramatically from the initial starting point.

Computers were quickly fitted with a keyboard in order to provide easy input to the computer in combination with screens and printers to generate output. Interaction with the computer proceeded by typing in commands in a text interface like the one depicted below. Such command line interfaces require extensive knowledge of the meaningful vocabulary that can be entered and executed by the computer.



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Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\Documents and Settings\RNG>cd..

C:\Documents and Settings>
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Figure 2. Command Line Interface (CLI)

Alternatives to the command line interfaces were investigated from a very early point since they were cumbersome and difficult to use even by trained specialists. The human mind is simply not naturally geared to remember specific command syntaxes and large amounts of abstract information. To overcome the disadvantages of the command line interface, the graphical user interface (GUI) was invented (Dourish, 2004; Tomitsch, 2003). In a GUI instead of remembering all sorts of commands and associated variables, the available and meaningful commands in a given context are made readily available directly as a graphical representation of buttons that can be clicked with a pointing device such as the mouse. It was also argued that the use of pictograms and icons instead of text provided a superior
support for memory of the meaning and functions of the buttons (ibid.)

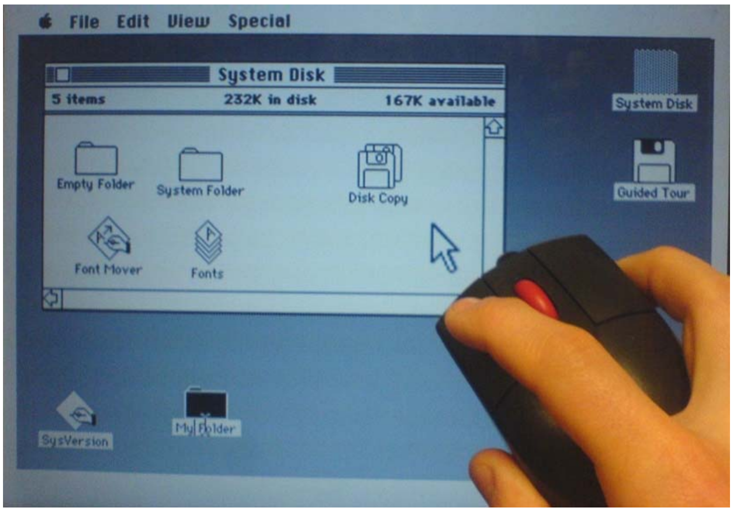


Figure 3: Apple Macintosh desktop graphical user interface (GUI) from 1984 and mouse

Modern computerized tools like the cell phone, the e-mail programme and video recorder draw heavily on the GUI symbolism in the form of text and icons in the way we operate and interact with them. The symbolic content of the graphical user interfaces are typically manipulated indirectly via buttons, such as “play” and “rewind” that are pushed directly with the finger or indirectly with a pointing device such as the computer mouse. The motor skills we use are thus highly stereotyped across many different types of computerized tools and functions. Consequently, computerized tools do not distinguish themselves in the way we interact with them from a sensory-motor causalfunctional perspective, but only by the meaning of the symbols we push and manipulate. A separate goal that grew out of graphical user interfaces was the concept of direct manipulation (Hutchins et. al., 1985). In direct manipulation the user acts directly with the mouse (or some other input device) on the graphical objects on the screen that bypasses indirect commands. For example, a picture in a text document can be resized directly by pulling its corners as an alternative to specifying its size as height and length in centimetres in a dialogue box. Direct manipulation has become even more direct with the advent of touch screens and applications to match them as seen in the Apple iPhone. In this way the pointing device has been altogether circumvented so the users, for example, can rotate and scale pictures up and down in size directly on the screen with pinching gestures.

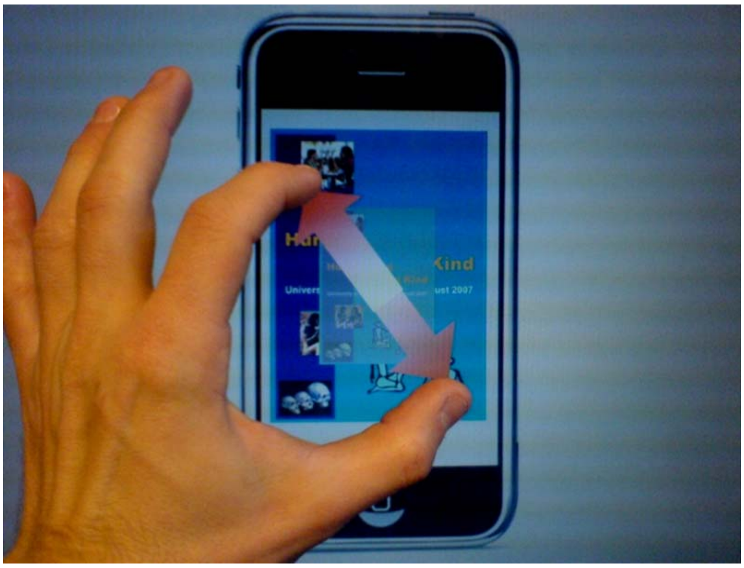


Figure 4. "pinch" gesture to resize a picture on the touch screen of the Apple iPhone

A final movement to be mentioned here is tangible user interfaces or simply tangibility, where the rich interaction from the direct manipulation framework is radicalised by letting all sorts of physical objects represent aspects of the immaterial elements from the graphical user interface (Dourish, 2004). One illustrative example is the conceptual marble phone answering machine where each new incoming voice message is represented by a marble and placed in a little tray on the machine that can be picked up and handled like an object. Where traditional immaterial voice messages are stored inside the answering machine only to be accessed and listen to by pushing buttons on a menu, the marble answering machine gives the messages a physical form by coupling them to the physical marble token (Wensveen, 2005). The goal is to exploit the physical constraints that material objects are per default subject to and hereby access our accustomed natural understanding of such objects and their behaviour (ibid).

Design of userfriendly technology draws on multiple disciplines, such as anthropology, sociology, psychology, etc. The approaches based specifically on cognitive theories, to make technology more userfriendly, from the GUI over direct manipulation to tangibility, all have underlying assumptions about what makes them more userfriendly. These assumptions typically fall into two categories:

The *first* is to reduce complexity and unburden our cognitive resources. For example, the transition from command line interfaces (CLI) to graphical user interfaces (GUI) reduces the need for the users to learn and remember all the viable commands and hereby unburdens the memory of the user. The direct manipulation approach similarly does away with various indirect commands that act on graphical representations of objects and allows the users to manipulate the object directly, with a number of limited and highly generic gestures. This further reduces the number of specific commands that have to be learned and memorised. The implicit notion behind these solutions is that we have a limited amount of cognitive resources that should be used sparingly.

The *second* approach has a radically different underlying assumption that is complimentary to the first. This approach acknowledges that we have a relatively limited amount of *conscious intellectual* resources but that these are only the tip of the iceberg (Bærentsen, 2000; Rasmussen, 1986). The vast majority of human cognitive resources are made up of highly automated subconscious resources (ibid.). Whereas intellectual resources are characterised as highly flexible and adaptable, the subconscious resources are in contrast rigid and optimised to solve very specific real world tasks, such as the manipulation of objects. The tangibility approach mentioned last reflects an effort to draw on these resources by letting immaterial data and logical functioning occupy tangible physical objects and so by proxy gain access to these basic cognitive resources.

A quick assessment leaves no doubt about the tremendous success of the classical graphical user interface (GUI). The widely used Microsoft Windows desktop GUI metaphor has become a standard on most computers in the world. The traditional GUI with menus and icons is also adopted in most cell phones and many other devices. There is thus no doubt that the approach to reduce complexity has been more viable than the approach to integrate and provide support for more basic cognitive resources.

If we compare the two approaches, GUI and tangibility, cognitive psychology has devoted much attention as to higher order intellectual skills as for example how adult memory works. Such rigorous research has helped pave the way for the GUI and similar solutions. In comparison, the tangibility approach mainly builds on an acknowledgement that we have resources devoted to handle objects naturally but only have a very crude understanding of the actual basic cognitive mechanisms involved. Without such a detailed knowledge of the basic cognitive dynamics, the only way to integrate support for these basic resources is to recast immaterial functional aspects of the technology directly in the shape of physical objects. Paul Dourish has framed the problem with the tangibility approach very well in his 2004 book “Where the Action is”:

> Our understanding of the nature of these problems is, so far, quite limited, certainly in comparison to the more traditional international style that characterizes most interactive systems today [GUI based]. The theories that govern traditional interaction have only limited applicability to this new domain. At the same time, tangible computing has been explored, largely, as a practical exercise. Most prototypes have been developed opportunistically, driven as much by the availability of sensor technology and the emergence of new control devices by a reasoned understanding of the physicality in interaction. We have various clues and pointers, but there is no theory of tangible interaction. Why does tangible interaction work? Which features are important, which are merely convenient and which are simply wrong? How does tangible computing mediate between the environment and the activity that unfolds in it?
> —Dourish, P. (2004, p.52-53). My insertions in brackets

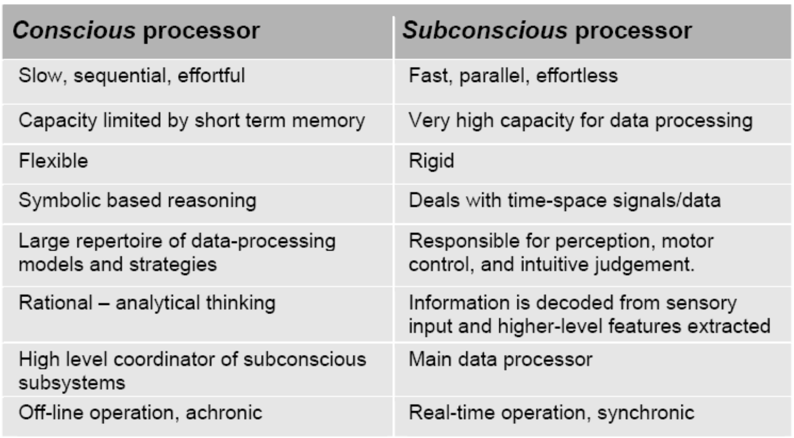
In this light it should potentially be possible to access the benefits of the vast resources by intimate knowledge of their structure and transform that into more flexible solutions that can be adopted by the widespread GUI solution. Recent years’ research in primate and infant cognition has done exactly that and has made it possible to outline the structure of the basic cognitive resources.

Basic and Intellectual Cognitive Resources

As humans we are easily fooled to believe that the majority of our cognitive resources help us solve problems like interpretation of the time schedule at the bus stop and filling out an insurance policy. Both tasks are highly intellectual in nature and draws on our cultural cognitive resources. Such skills are part of what Jens Rasmussen (1986) calls the conscious processor, since they are tied to conscious processes and we have to put in a conscious effort to engage them. Contrary to our phenomenological experience, however, most of our cognitive resources are tied to basic sensory-motor skills which, for instance, make it possible for us effortlessly to catch a ball and navigate between people on a crowded sidewalk (Bærentsen, 2000; Rasmussen, 1986). These sensory-motor skills are part of what Rasmussen (1986) calls the subconscious processor. The broad distinction between higher order symbolic intellectual processes and lower order basic sensory-motor processes is general to most psychological theories of cognition although it is labelled under different names (Velichkovsky, 1990, 2002). In the following brief outline of the characteristics of the conscious and subconscious processor the terminologies used by Jens Rasmussen (1986) will be adopted.

According to Rasmussen (1986), the *conscious processor* is highly adaptable to novel situations due to its flexibility and rational analytical problem solving abilities. It operates with symbolic information and is thus closely tied to our linguistic abilities and our conscious attentional control. This in turn makes it relatively slow, sequential, effortful and limited by the capacity of the short term memory. This dependence on conscious control and willed effort also makes it very fragile and susceptible to breakdowns in stressful and multitasking situations. The conscious processor relies on learned data processing strategies and models. Human performance on tasks that rely heavily on the conscious processor will as a consequence show great variability that depends on the efficiency of the strategy used (Rasmussen, 1986). The conscious processor is also the high-level coordinator of the subconscious system.

The *subconscious processor* deals with data in terms of what Rasmussen calls time-space signals as opposed to symbolic information as it is naturally evolved to deal with functions of sensory-motor control. The major limitation of this subsystem is that it is only capable of dealing with familiar, frequently encountered situations like the ones the organism has adapted to. The high degree of specialisation of the subconscious processor makes it highly efficient and combined with massive capacity that stem from parallel processing, it is both fast and effortless. In contrast to the conscious processor this system is more robust against stress and breakdowns.



***Conscious* processor**	***Subconscious* processor**
Slow, sequential, effortful	Fast, parallel, effortless
Capacity limited by short term memory	Very high capacity for data processing
Flexible	Rigid
Symbolic based reasoning	Deals with time-space signals/data
Large repertoire of data-processing models and strategies	Responsible for perception, motor control, and intuitive judgement.
Rational – analytical thinking	Information is decoded from sensory input and higher-level features extracted
High level coordinator of subconscious subsystems	Main data processor
Off-line operation, achronic	Real-time operation, synchronic

Figure 5. Traits of the conscious and subconscious processor. Adopted from Vincente & Rasmussen, 1988

The distinction between basic sensory-motor skills (the subconscious processor) and higher order intellectual skills (the conscious processor) ties in very well with the duality of tools as both objects and cultural artefacts. To fully appreciate the cognitive premises of human tool use, and especially computerized tool use, we must therefore draw on theories that address both the dynamics of the conscious and subconscious processor.

Higher order intellectual skills have traditionally been well studied inside the information processing cognitive science framework (Velichkovsky, 1990, 2002). Indeed many theories of human cognition co-evolved in close relation with the field of human-computer interaction (Hoff, 2004). There is thus a historical correspondence between the logics of computerized technology and the theories of higher order cognitive skills. Theories and methodologies of human use of computerized technology are as a consequence naturally focused on higher order cognitive skills (ibid.). Methodologically and theoretically there is thus a large repertoire to draw on in the design and development of modern computerized technology in relation to cultural aspects and conscious higher order intellectual skills.

The theoretical and methodological corpuses that support how we understand the role of basic sensory-motor processes of the subconscious systems in relation to computerized technology are in contrast much less evolved (Dourish, 2004; Bærentsen & Trettvik, 2002). Several reasons can be mentioned that may account for this. *First* the historical aspects of the correspondence between computerized technology and higher order cognitive skills naturally evolved this area in contrast to basic skills that did not have a natural counterpart in the development of programmed technology (Hoff, 2004). *Second*, the phenomenological bias of higher order cognitive skills naturally drew attention to their role in behaviour. *Third*, computerized technology was initially developed in the realm of highly intellectual uses by skilled professionals operating large complex industrial installations with a focus on supervisory tasks (Bærentsen, 1996; Rasmussen, 1986). *Fourth*, owing to the legacy of developmental psychologist Jean Piaget, the implicit notion of humans born as cognitive blank slates, the subconscious processor was easy to conceive merely as a highly adaptable system of sensory-motor space time signals without any phylogenetic derived structure. In other words the subconscious processor was a structureless slave to higher order intellectual dynamics one needed not concern about (Nørager, 2004). *Finally*, the dynamics of the conscious and subconscious processor makes it difficult to isolate problems that occur when computerized technology does not support the subconscious processor. For example, when you move the mouse to a position where you expected something to be on the computer screen – such as the print icon in Microsoft PowerPoint - this rapid and precise movement is supported by basic orientation and positioning skills. You then suddenly realise that the print icon has disappeared or been relocated. In such a breakdown in our use of the computerized artefact the focus shift causes conscious attention to be drawn to the nature of the problem whereby, for example, search routines helps us realise that the print icon has been relocated higher in the menu list due to that how other seldom used menu items have been removed.

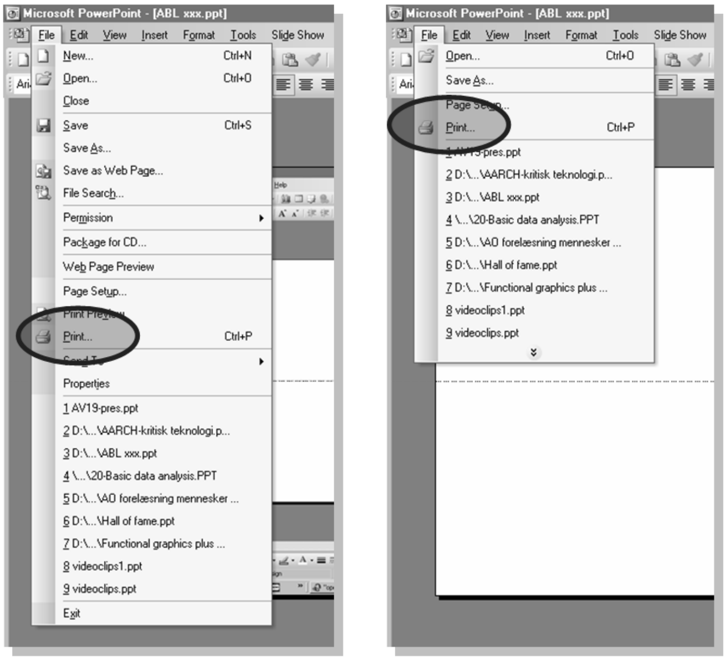


Figure 6. Dynamic pruning of seldom used menu items in Microsoft Office causes the position of the other menu items to shift around.

What poses a problem or incompatibility with basic cognitive skills will most likely not be so in relation to conscious cognitive intellectual skills since they exhibit flexibility, adaptability and rational analysis. We simply acknowledge that the icon is in a new position and consciously guide the mouse cursor to this new position and click it. In other words, the problem seems to dissolve the moment we consciously focus on it!

To counter these historical and methodological biases primate cognitive research and developmental psychology seem well suited to investigate these basic abilities and their dynamics in their pure form for several reasons. *First*, since much research has already been done, it is only sensible to try and apply it in a novel way. *Second*, higher human intellectual skills are very flexible and adaptable, which makes us so prominent in the animal kingdom. Unfortunately, in a research setting these very skills often make it difficult to investigate the limits and evaluate breakdowns of specialised basic cognitive skills. The reason being that when breakdowns occur higher cognitive abilities will simply shift in and take over. Hereby the incompatibility problem as such ceases to exist. *Third*, basic cognitive skills are often tacit in nature and not immediately accessible to human phenomenological introspection (Bærentsen & Trettvik, 2002). In experimental conditions we therefore cannot rely on verbal reports. Paradoxically, the cornerstone of methodologies to evaluate usability of computerized technology and one of the most widely used inspection protocols in human-computer interaction is the “think aloud protocol” where users are asked to verbalise their continuous stream of conscious thought when they use and evaluate a computerized product (Rubin, 1994). *Fourth*, the conscious experience we have of how we interact with the physical world has proven in some ways to be contradictory to its true nature and sometimes rather counterintuitive (Hermer-Vazquez, Spelke & Katsnelson, 1999), which further biases the conscious phenomenological approach.

The non-verbal premises of research with animals and human infant have generated novel and ingenious research designs that allow us directly to probe the dynamics of basic cognitive skills without having to rely on verbal reports. This has also positively influenced research on adult humans and provided us with optics that overcome challenges normally associated with experiments that probe basic subconscious abilities.

Primate Cognition In Computerized Technology

The attempts so far to tap into basic cognitive resources of the subconscious processor has primarily been to let the immaterial functional logic of computerized software code inhabit physical tangible objects. As Dourish, however, underlines we have no precise knowledge of what the functional effective aspects of this solution is, other than it allows the user to interact naturally with these physical computerized objects (Dourish, 2004). With intricate knowledge about what the functional properties that make tangible computing work, it can be argued that in addition to letting computerized functionality inhabit physical objects we can also let the physical functional constraints of the physical world populate and inhabit the computerized world. Hereby we can potentially profit both from the advantages of the widespread classical GUI approach and the benefits from the tangibility approach. The possible viability of this approach can be illustrated with the evolvement of animated cartoons.

In the early days of animated cartoons it was only possible to tell very basic and short stories. Longer animated stories with complex narratives did not work because the characters did not seem convincing to the audience and generally lacked a natural look and feel which made them ungainly and awkward (Lasseter, 1987). One of the great feats of Walt Disney was to overcome these limitations by making detailed kinematic studies of animate and non-animate object behaviour dynamics. These detailed studies where crystallised into eleven animated cartoon principles that among others capture the functional essence of how animate and non-animate bodies behave in the physical and social world (ibid.). By implementing these kinematic dynamics into the cartoons, Disney made cartoons look “right” and thereby opened the cartoon industry to longer and more complex narratives. Indeed Disney and his cartoonists with these principles had the skills to create arbitrary anthromorphic characters and endow even a sack of flour with animate properties. Profoundly enough, when the computer industry made it possible to generate animated characters that on the surface looked almost like the real world - something hand animated cartoons could never achieve - they failed because they had overlooked Disney’s original intrinsic cartoon animation techniques. It took John Lasseter and his team at PIXAR studies to reintroduce the animation techniques to computer animated cartoons (Lasseter, 1987). The lesson learnt once again was that the functional aspects of the physical world in relation to agents and objects lie in the intrinsic dynamics and not in the phenomenologically “defining” surface characteristics. The ability to endow even triangles with mental states when the dynamics of the animation are right is beautifully illustrated in the studies by Abell, Happé & Frith (2000) with normal and abnormal autistic children’s appreciation of abstract animated characters.

Such examples illustrate that with the proper knowledge of the intrinsic functional dynamics these can be transposed onto other objects, even though they may lack the surface characteristics of the natural objects. It was therefore natural that the work of Disney and Lasseter was adapted into graphical user interfaces that people in general also tend to perceive and conceptualise in categories of scenes, objects and agents (Bærentsen, 2000). In their article from 1993 Chang & Ungar (1993) outline how principles from animation can be applied to the user interface. However, they call for further research to determine and clarify the detailed dynamics and the effects of doing so (ibid). Like tangible computing although it works we do not know why.

To summarise, the approach to endow the graphical user interface with functional dynamics from the physical world, towards which our subconscious processor is naturally adapted, seems warranted. The approaches by Disney, Lasseter, Chang & Ungar, however, still suffer from the same bottom up experiential driven approaches which Dourish challenges with the tangibility approach. In addition, we need a coherent theoretical framework from which hypotheses can be derived and subjected to experimental investigations. The core knowledge framework most noticeably represented by the research of Elisabeth Spelke and her colleague is a good departure point towards such a framework.

The Core Knowledge Paradigm

To recapitulate on what we have addressed to far the following points are outlined:

- Computerized technology is functionally abstracted from the material basis that characterises material tools.
- The human subconscious processor is optimised to deal with certain functional dynamics of the material aspects of tools.
- Research and practical examples suggest that these functional dynamics from the physical world can be implemented into immaterial graphical user interfaces.

The next challenge is thus to address systematically what these functional dynamics are, which the subconscious processor is optimised to deal with. One particular coherent framework that also builds on rigorous research has been advanced by Elisabeth Spelke and her colleagues. Based on an adoption of Fodor's contemplation of basic cognitive modules, they have devised the idea of core knowledge (Spelke, 1994, 2000; Spelke & Tsvikin, 2001; Spelke & Kinzler, 2007). The core knowledge research paradigm has so far experimentally outlined four core knowledge domains (Spelke, 1994; Spelke & Kinzler, 2007). These are representational systems that relate to:

1) Object dynamics
2) A small exact and large approximate number system
3) Spatial orientation based on geometrical relationships (ibid.).
4) Agents and rational goal directed behaviour

Although the object representational system has been studied most intensively all four system have received much experimental and theoretical attention.

Due to the massive research attention related to the core knowledge paradigm, the field has moved forward quickly and generated many well documented findings alongside with novel and ingenious methodologies. It is important to stress that despite general agreement on many research findings the specific core knowledge conceptualisation of these findings is still very much debated. For a critical discussion of core knowledge I refer the reader to Cheng & Newcombe (2005), Newcombe & Huttenlocher (2003) and Newcombe & Uttal (2006). Based on the large amount of empirical evidence, it seems, however, warranted to adopt some of the most well established and generally agreed upon findings into the applied field of computerized technology design. Two of these findings are core knowledge about objects and their behaviour and core knowledge about spatial navigation.

One of the special features of the core knowledge framework is the special role of language as a resource that integrates and overcomes the constraints of the basic core knowledge systems (Spelke, 1994, 2000; Spelke & Tsivkin, 2001). This flexible role of language is dynamic which means that the extension of basic cognitive competencies into the cultural domain must continuously be furnished by higher order linguistic cognitive skills. If the linguistic skills are occupied, as it has been experimentally investigated in dual task paradigms, results indicate that adult humans in some ways base their behaviour in relation to orientation and other agents on the more isolated and basic functions of the core knowledge modules (Hermer-Vasquez, Spelke & Katsnelson1999; Newton & de Villiers, 2007). Since computerized technology by nature is very demanding on our linguistic and symbolic cognitive skills, as outlined previously, this aspect accentuates the need for computerized technology to support basic core knowledge dynamics of human cognition more directly.

Core Knowledge of Space and Objects in Graphical User Interfaces

The final step is experimentally to investigate the value and effect of designing key core knowledge dynamics into graphical user interfaces. Based on the theoretical analysis we developed the hypothesis that graphical interfaces constrained with core knowledge dynamics should:

1) Be more intuitive and easy to use
2) Be faster and generate fewer errors
3) Be more pleasurable to use due to fewer breakdowns and less intellectual cognitive strain.

In order to test this hypothesis two typical graphical users interfaces were identified that most users of contemporary computer systems should be familiar with. Both user interfaces came in two versions, A and B. The A versions violated either spatial- geometric orientation relations or spatiotemporal object dynamics. The other B-versions of the two graphical user interfaces were manipulated in order to comply with the respective core knowledge dynamics of space and objects. Both graphical user interfaces thus came in two versions that were graphically similar in their surface characteristics but different in their intrinsic functional dynamics.

The *spatial* core knowledge paradigm interface consisted of a windows folder list that users had to navigate in. The paradigm conceptually resembled a situation where you have to go in and out of offices located on a long office hallway. The test conditions would be akin to A) always (magically) to return to the entrance of the office hallway when you exit an office no matter how long the hallway it located. Alternatively B) you always return to the precise position in the office hallway where you entered the office.

The *object* core knowledge paradigm consisted of a list with graphical icons of TV channels. The list had to be resorted rearranged by moving the channels one at a time from the position in the list to the right and then either up or down to a new position. The paradigm conceptually resembled a situation where you have to move books around on a bookshelf. The movement from left to right and vice versa (in and out of the bookshelf) could either be A) instant (magically) or B) animated as a continuous movement.

In two series of counterbalanced experiments 56 participants solved a number of structurally equivalent tasks in both versions, A and B, of the two types of interfaces. Participants were recruited to control for experience with computers, age and sex. After the experiment the subjects were interviewed to probe for their phenomenological subjective experience.

The preliminary results from these experiments are very encouraging (Nørager, 2006, 2008A, 2008B). In both experiments the B-versions that did not violate the core knowledge dynamics were significantly preferred over the other A-versions by the participants. There was also a small difference in the time the participants took to solve the tasks with the versions that did not violate core knowledge being the fastest to use. In our analysis of the data we also quantified how confused the participants were in either of the two B-versions based on the movement pattern of the mouse cursor and how many errors they made. We found that in both types of graphical user interfaces the users made significantly fewer errors and were significantly less confused in the B-versions that did not violate the core knowledge dynamics. Some of these differences related to how confused the participants were turned out to be not only significant but quite extreme.

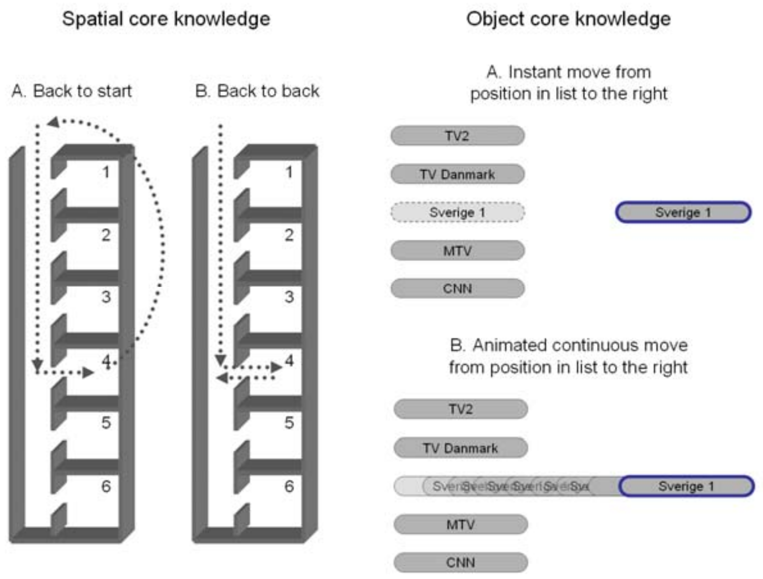


Figure 7. Spatial core knowledge was tested in a folder navigation paradigm akin to an office floor hallway. Object core knowledge was tested in a TV channel object move paradigm.

In our interpretation of the data we have focused on the relation between the relatively small functional time difference and the sometimes huge difference on more qualitative and phenomenological aspects. Here the theoretical framework provides us with explanatory insights in relation to the dynamics between higher order and lower order cognitive dynamics. Although the participants made substantial errors with the A-version graphical user interfaces that violated core knowledge dynamics and were highly confused by them, they were also able to recover from these breakdowns during the interaction. The recovery from a breakdown is, however, a demanding intellectual task, akin to problem solving, which moves focus from the current activity and causes cognitive strain. Although these breakdowns did not impact time consumption drastically in the A-version interfaces that violated core knowledge dynamics they did, however, irritate and annoy the users very much despite the quick recovery. This was also evident by some of the participants' overt exclamations of dissatisfaction and annoyance like deep sighs. This relation is probably what is reflected in the major preference difference in favour of the B-version user interfaces that did not violate the core knowledge dynamics. In summary, programmed technology that functionally constrains to the dynamics of the physical world is thus not only functionally superior but is also vastly more “aesthetically” pleasing to use.

Two other findings in the data are important in relation to the nature of core knowledge dynamics. *First*, both Hermer-Vasquez, Spelke & Katsnelson (1999) and Rasmussen (1986) note that persons’ performances based on intellectual competencies are more varied due to the differences in efficiency of various strategies adopted. Performance based on basic cognitive resources is much more similar due to the uniform subconscious nature and evolutionary background in contrast to individually and culturally appropriated skills. This contrast also seems to be reflected in our data. The variance on all measured dependent variables in the experiment was significantly larger in the data associated with A-version user interfaces that violated core knowledge dynamics. This can be explained by the greater need for the participants to rely on intellectual strategies to solve the tasks and overcome the breakdowns in the interaction associated herewith, i.e., some users adopted better intellectual compensatory solution strategies than others. *Second*, in the follow up interview to the experiments, the participants were asked for their preference regarding the two versions of the graphical user interfaces. As reported previously, the participants highly favoured the B-version graphical user interfaces. When asked why they preferred one over the other, almost half of the participants in the object interface paradigm were unable to account correctly for their preferences as related to the dynamical difference between the two. This fits very well with the subconscious nature of core knowledge dynamics. The participants are not able consciously account for the true nature of their dissatisfaction and pinpoint the origin of the breakdowns, simply because they do not have immediate conscious access to those cognitive layers. Unable to account correctly for the difference between the two versions as rooted in the functional dynamics, these participants would instead rationalise and provide *incorrect* accounts linked to difference in surface characteristics that was not actually there. Hermer-Vasques, Spelke & Katsnelson (1999) reported similar findings with adult subjects who were unable to account correctly for how they had reoriented in a dual task orientation experiment that forced orientation to rely on more basic core knowledge orientation skills.

To summarise, we have provided support for the hypothesis on different levels. The raw scores on performance provide support for the hypothesis that graphical user interfaces that do not violate core knowledge dynamics are easier and more intuitive to use. The users also experienced fewer breakdowns and therefore had to use less intellectual cognitive resources to overcome the breakdowns, which seem to make the graphical user interfaces more enjoyable to use, as reflected in the preference measure. The data structure, which closely matched each other across two very different tasks and user interfaces, also points to a common mechanism in play, which further supports the core knowledge dynamics as a common conceptual framework for understanding these data.

As a final note, it can be added that since the tasks deployed in these experiments were very easy it can be further hypothesized that if these experiments had taken place in a stressful situation or involved secondary tasks, the quantitative difference in time might have been more outspoken due to more severe breakdowns of the overall interaction with the non-core knowledge versions. This will be the focus in upcoming experiments.

Closing Remarks

Tool use from an animal and infant cognitive developmental perspective highlights the duality of human tool use as both causally, functionally and culturally constrained. On this background, computerized technology singles itself out by its lack of a causalfunctional basis. The importance of the causalfunctional basis was illustrated by the basic cognitive resources naturally dedicated to support activity in this respect. Animal cognitive psychology and infant developmental cognitive psychology have successfully studied the functional properties of these basic cognitive skills both in primates, human infants and adults. This research agenda has given rise to a coherent framework called core knowledge. Based on this approach, it seems possible to re-implement support for the vast basic cognitive resources in modern computerized technology. The deep nature of computerized technology as essentially disembodied from a causalfunctional basis is hereby possible to overcome. In a sense, the challenge is to re-establish the functional essence of the causal-functional properties in computerized technology.

The conception of the basic subconscious cognitive skills, which is reflected in the core knowledge theoretical framework, makes it very well suited to generate hypotheses about how human adults' use of computerized technology can be experimentally investigated. This was done in two experiments from which preliminary data on a number of levels provide support for the viability of this approach.

On a more general level, the animal and infant cognitive developmental framework adopted in this article dictates that the problems many users experience with computerized technology is not a generational problem that will disappear as younger generations become more accustomed to such technology. The problems with computerized technology lie at the very heart of our cognitive resources which have a long evolutionary history. Instead it might be said that younger generations are more accustomed to compensate intellectually for the shortcomings of computerized technology than older generations. Furthermore, due to the tacit nature of these subconscious skills we cannot expect either that technology will eventually evolve out of these problems on its own as many other technologies mature. Instead, it will require a focused scientific effort to find the functional dynamics of the core knowledge systems needed to help remedy the problem. Animal cognitive psychology and infant developmental cognitive psychology have proven to be two very promising directions to pursue in order to help guide the design of future computerized technology.

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CHAPTER SEVEN

BEYOND GROOMING: DESCARTES' COGITO AND A DARWINIAN NEUROPSYCHOANALYTIC VIEW OF UNIQUELY HUMAN MENTATION

HARRY R. BRICKMAN

Abstract: This paper begins by deconstructing Descartes' Cogito as referring to self-reflective thinking, which it argues to be uniquely human. Further examining Descartes' Meditations, it proposes and illustrates that the thought processes in contemporary neuroscientifically-informed psychoanalytic depth psychotherapy are prime examples of reflexive thinking unique to Homo sapiens. It also postulates a continuum of succorance among mammals, from arched back nursing in rats, through grooming in non-human primates to supportive elements of psychotherapy and psychoanalysis in humans. New research is called for on the selective value of unconscious conflictual neural processes, the acknowledged domain of psychoanalytic depth psychology. Since the paper is not primarily intended for clinicians, no detailed case material will be presented.

Introduction: What Descartes meant by "Cogito *ergo sum*"

A strict reading of Descartes supports a seemingly paradoxical view of the self-reflecting properties of the human mind that this essay proposes as unique among all animals. *Cogito ergo sum,* the Latin translation of *je pense, donc je suis* appeared in his *Discourse on Method* (1637):

I was then in Germany, attracted thither by the wars in that country, which have not yet been brought to a termination; and as I was returning to the army from the coronation of the Emperor, the setting in of winter arrested me in a locality where, as I found no society to interest me, and was besides fortunately undisturbed by any cares or passions, I remained the whole day in seclusion, with full opportunity to occupy my attention with my own thoughts.

Without claiming to be a Latin scholar, it appears likely to me that the French words *je pense* appear to be most closely derived from the Latin *pensito* – I weigh, weigh out (Lewis and Short 1879). Since Descartes himself translated his French words *je pense* into the Latin *cogito*, it seems arguable that he intended a specific connotation of weighing, pondering, considering, rather than of propositional thinking (E.g.: I think *that*….).

I therefore suggest that – *think* that – Descartes' choice of language did not mean thinking in the sense of "thinking that" or "thinking of" or even "thinking about" .It can be understood as a mental activity of an intransitive nature – the kind of reflective thinking engaged in by philosophers and by poets, who often call it soliloquy. An outstanding example is Shakespeare's *"To be or not to be"* soliloquy in *Hamlet.* The renowned sculptor Auguste Rodin also captured self-reflection in his masterpiece, *The Thinker.*

Reflective thinking is perhaps more a mental state than a mental action (Brickman 1998). I will then be so bold – or so foolhardy—as to suggest that the Latin word *meditatio* would have better approximated Descartes' idea, if indeed he was parsing words at the time. In partial confirmation of my speculation, Descartes entitled his next work *"Meditations"* (1641). My contention, then, is that Descartes' C*ogito* referred to deeper-level cogitation or meditation, and therefore self-reflection. The mind, *qua* mentation, is a loosely defined term referring to the parallel and distributed processing of information within the brain which can include attention, concentration, planning, memory storage and retrieval., rehearsing (within the inner representational world), licking of psychic wounds, and other executive functions as well as dreaming.

Mentation is mainly non-conscious, but in part can also be willingly conscious, and this is also true of self-reflection. Self reflection is an elaboration of theory of mind, the capacity to identify the intentions of conspecifics. Still-controversial reports from many primatologists (E.g. Whiten 1991, DeWaal 1996) indicate that chimpanzees employ theory of mind, or mentalization, in scanning the intentions of conspecifics.

More recently, experiments by Hare, Call, and Tomasello (2001) have refined our understanding of theory of mind behaviors in chimpanzees under competitive conditions which reveal the nuanced nature of that realm of mentalization. Hare et al. have been able to demonstrate the socially adaptive value of theory of mind in subordinates who can, under laboratory circumstances, evade dominant animals in securing food. There are no findings that I am aware of that confirm a capacity to *mentalize one's own thinking* in any non-human animals.

According to Hauser (2000), spider monkeys think, cats think, corvids and scrub jays think, elephants think, dolphins think. According to most dog owners, dogs also think. Humans are known to think, but what other animals beside humans cogitate, self-reflect, meditate, soliloquize, --- *think about thinking*? Regret their thoughts? Experience self-pride or self-contempt? And how can these questions be researched?

The species- significant criterion of self-reflective thinking

Self-reflective thinking fundamentally requires a splitting of self-function--or agency--into two components, the observing self and the observed self (I will be discussing the concretization of mental processes into mental entities presently). Self-reflection is an evolved aspect of theory of mind; often, but not always, implemented in the undisturbed solitude that Descartes described. It is a conversation within one's inner representations of self and of the outer world when the distractions of that outer world do not require the energy for complex mentation and actions devoted to furthering personal and genomic survival. Self-reflection also enables self-narrative formation, again a uniquely human capacity as far as we know. In turn, the role of self-reflection – also known as reflexivity – has been significantly redefined by contemporary psychoanalytic researchers and clinicians who have been influenced by evolutionary biology and psychology (Fonagy et al.2001) The Fonagy group has built much of its work on the evolutionary arguments of John Bowlby (1969) who located the early emotional development of humans within a continuum of succorance in mammals.

Arguments for a continuum of succorance in mammalian – including human – life

Grooming, licking, and arched-back nursing in laboratory rats increase hippocampal synaptogenesis and promote cognitive development in pups, according to Liu at al. (2000) at McGill. Naturalistic and in-captivity observations of non-human primates provide evidence of what I would call *alloregulation,* by which I mean affect regulation in one individual through specific behaviors of another conspecific. Anthropoid apes and monkeys have evolved such down-regulating practices in the form of grooming behaviors. In the absence of effective auto- or self-regulation of propensities for socially disruptive or destructive behaviors, grooming has evolved to promote individual comfort and subsequent self-control, thereby facilitating group solidarity, so vital to individual survival of social animals in ancestral and contemporary environments. By down-regulating potentially disruptive affects in individuals, grooming also lubricates social exchanges in dominance hierarchies. Concordant behaviors are thereby furthered, signaling reconciliation, ranking acknowledgement, and peacemaking, along with succorance. (DeWaal 1996, esp. pp.40-88 & 176-182). DeWaal acknowledges, however, that the "double-holding" behaviors of rhesus mothers who pick up and briefly hold infants of higher ranking mothers has only been observed at the Wisconsin Primate Center (DeWaal 1996 pp.100-101). This is an example of a researcher acknowledging the limitations of generalizing behaviors observed in captive animals, as Boesch (2007) has underscored more recently.

Similar practices occur in packs of canids in the form of licking and assumption of vulnerable, often sexually receptive, body positions. (Solomon & French 1997) Other, less intense and prolonged, examples are in the necking of horses (who are herd animals in the wild), and analogous alloregulatory behavior in other non-primates.(see Riedman 1982). Similar behaviors are regularly observed in impalas, giraffes and elephants. Mutual face and neck rubbing has been frequently observed in prides of lionesses in the wild (Buechner 1973).

In humans, alloregulation is expressed in handshaking, hugging, holding, and stroking in families and close friendships. It is common in American society to feel "touched" by a particularly poignant event. Within the past decade, the developmental advantages of touch in early human infancy have been researched in an increasing number of academic medical centers (Field 1996). The more intimate grooming represented by kissing occurs not only in humans, but in chimpanzees and bonobos as well (de Waal 1996). On further consideration, evidence of skin-contact succorant behaviors akin to grooming exists across most observed mammalian species. DeWaal (1996 pp.40-45) discusses this behavior in dogs and whales as well as primates. A patient of mine, temporarily bedridden with severe neck pain, was touched softly on the cheek by his pet cat (after she had eaten).

On comparative psychology and the *sapiens sapiens* of *Homo*

The arguments for a continuum of succorant behaviors would tend to bracket the long-standing nature vs. nurture debate within anthropological circles, revived recently by Boesch (2007), by not claiming validation for either point of view. As proposed earlier in this paper, the uniquely human capacity for self-reflection is postulated, in the absence of empirical studies, to be an outgrowth of theory of mind (TOM). Perhaps Boesch's distinctions between developmentalist and deterministic approaches apply to the reports of evidence of TOM in some chimpanzees, gorillas and orangutans as well as some cetaceans and domesticated dogs, cats, and parrots. Refinement of these findings may well be in order, although it would not negate the argument that self- reflective thinking is limited to our (putatively) doubly wise subspecies.

Evolved grooming in *Homo*

A significant aspect of contemporary medical care, beginning with a history of *curanderos* and other healing functionaries in early societies, includes varying degrees of succorance, including hypnosis, moxibustion, acupuncture, acupressure , chiropractic, and placebo effects. These procedures can be regarded as examples of evolved grooming. The alloregulation (downregulation) of pain and discomfort achieved by such procedures often occurs through the activation of endogenous opioids in the brain. The increasing establishment of alternative medicine departments in several prominent U.S. academic medical centers, i.e. Harvard, UCLA, and Columbia , reflect a new-found respect for the efficacy of these methods.

Avuncular teaching, counseling, and supportive psychotherapy can be considered as types of evolved succorant grooming in humans. This is especially true of massage, cosmetic services, barbering and hairdressing. Earlier in my career, when faced with the task of building a large metropolitan community mental health program, I hired a psychiatrist from another state who had created a smaller local program providing mental health consultation to barbers, bartenders, and hairdressers. All of these serve in most North American communities as front line–although informal–listeners and advisors to their troubled clients and customers. (Brickman 1964)

The roots of psychotherapy in succorant grooming

In the arena of professional caregiving, supportive psychotherapy provides empathy, compassion, instructive advice, and manual-based psychological exercises for those who signal a desire for help. These services can be regarded as evolved grooming consistent with language acquisition in social exchange. Psychotherapy based on depth psychology, such as psychoanalysis, despite denials by many of its practitioners, has been acknowledged by influential contributors in the field to often provide minimal levels of verbal support (Wallerstein 2000). This underlines the evolved roots in grooming of this supposedly ‘interpretation-only’ therapeutic interchange. It is even arguable, for example, that maintenance of the “frame” of time and space parameters so strongly advocated in conventional analytic circles as essential for establishing a secure base for the patient is also rooted in the alloregulative functions derived from a continuum of grooming behaviors.

Most psychoanalysts and psychodynamic therapists, however, agree that deliberate provision of support in the therapeutic encounter is unwarranted for several reasons, not the least of which is that it can actually impede self-reflection and eventual auto-regulation. On the other hand, many psychoanalytic investigators (E.g. Bion 1963, Winnicott 1965) identify sensations of being “held” as integral to a patient’s therapeutic experience. It must be added that such “holding “is strictly figurative in psychoanalytic therapy. It refers to a nurturant type of succorance akin, in the patient’s subjective experience, to a marsupial relationship. Most contemporary psychoanalysts probably consider actual holding as likely grounds for ethical complaint, by virtue of the “slippery slope” cautions of analytic ethicists against erotic enactions in therapeutic relationships. In the case of patients who live drastically alienated and isolated lives as a result of early and repeated traumatic experience with caregivers, a carefully titrated amount of literal, but non-erotic, touch by experienced clinicians may be in order with the intent of facilitating trust.

Self-reflective thinking, succorance, and psychoanalytic process

Aside from meditation (and perhaps contemplative prayer), the most intensive patterned self-reflection is instantiated by the psychoanalytic process, which itself can be conceived as a joint meditation. In this interaction, the nominal patient self-reflects verbally in the presence of a presumably trusted self-reflecting other. That joint undertaking, exploring the patient’s inner representational world, is intended to reduce or possibly eliminate anxiety, shame, depression, imprints of early psychic trauma, as well as self-defeating behavioral patterns and social failures resulting from psychopathology. (Psychoanalysis is meant in this essay to include other socially sanctioned psychotherapies that apply psychoanalytic understandings of human subjective experience, development, and behavior.)

As an essentially verbal interchange, psychoanalytic therapeutic practice constitutes succorant behavior which goes beyond grooming. It pivots on the uniquely human capacity for self reflection and the use of language. Although its interactions are primarily verbal, an increasing number of psychoanalysts practice, and advocate, acute clinical awareness of prosodic nuances, bodily states ("body language") and neurocirculatory changes, such as blushing, sweating and increased respiratory rate, in their patients (Stern et al. 1998). These non-verbal phenomena are regarded as clues to either conscious or unconscious affect states. In sum, self-reflective thinking is an obligatory portal for seeking psychodynamic help, or succorance, and succorance in turn has a long evolutionary history in pre-verbal mammals mediated through bodily contact and grooming behaviors.

Darwinian neuro-psychoanalysis: accommodating a new synthesis

Freud's depiction of a universal *epistemophilic instinct* (Freud 1909) can be said inductively to energize much of the unique self-reflective capacity of *Homo sapiens sapiens.* In other words, a uniquely human need to assign meaning to subjective experience helps to generate the self-reflected *cogito* that made Descartes famous. The very *non-Cartesian* findings of cognitive neuroscience, by highlighting the emotional foundations of all socially interactive behavior, identify neuronal plasticity as one of the major neurobiological attributes enabling change under the impact of the analytic process.

Specifically, the encodings of implicit and procedural memory have been found to be modifiable through psychotherapy (Tronick 2001). The approximation of evolutionary biology and cognitive neuroscience amounts to a new synthesis for psychoanalytic theory. This new synthesis has been enhanced, for instance, by the experimental studies in molecular biology by the Nobelist psychiatrist Eric Kandel (1998, 1999), who views psychoanalysis as potentially enriching neurobiology in attempts to understand the vicissitudes of human mentation and behavior.

It is important to add at this point that brain science is still at a very early stage in its development, and has many years to go to reach its proper maturation. The suppositions underlying many of this essay's examples of reconciled neurobiological and psychoanalytic thinking, despite their identified bases in empirical studies, reflect an expectation that further studies will update and eventually supplant current neurobiological as well as conventional psychoanalytic thinking.

In that vein, most natural and social scientists are unaware of recent advances in psychoanalytic theory and clinical practice that embody significant footnotes and emendations to Sigmund Freud’s original instinct theory (Freud 1933). While educated as a neuropathologist, Freud found the localizationist hypotheses of the neurologists of his time thoroughly improbable, and, while maintaining that psychoanalytic theory should be built upon a biological bedrock (Freud 1932), he reluctantly departed from the umbrella of natural science in favor of a pure, largely disembodied psychology (Solms and Saling 1986). (“The” dynamic unconscious, for example, could not be localized in a specific anatomical area of the brain. In actual fact, recent neurobiological understandings of the widespread neural connections involved in all psychological functioning no longer imply that specific non-sensory and non-motor processes can ever be locatable in such a geographic manner).

This disembodied portrayal led to classical Freudian theories of development and psychopathogenesis that portrayed an individual beset with unconscious conflicts between instinctual urges seeking satisfaction and opposing intrapsychic elements attempting to forestall negative and self-defeating behaviors by means of symptomatic compromise formations. While the evolutionary significance of instinctual forces (the”id”) and the fundamentally social nature of the human species were implied in the concept of the “super-ego”, psychoanalytic theory and clinical process were cast in a mechanistic model of intrapsychic conflict known as metapsychology. Therapy was devised to bring these conflicts to awareness by undoing repression through free association and dream interpretation on the analyst’s couch. Because of their lack of conventional empirical verifiability, these theoretical speculations were prime targets for disparagement and scorn from a wide variety of scholars in the natural and social sciences (E.g. Grunbaum 1986) As recently as 2004, a renowned neuroscientific researcher saw fit to refer to “the notoriously lax intellectual standards of Freudian psychology” (Ramachandran 2004 p.8). To a psychoanalyst increasingly informed by Darwinian neuroscience, a prevalent continuing aspect of psychoanalytic conceptualizing can in fact be justly labeled as notoriously lax.

A regrettable effect of Freud’s conceptual migration from his neurophysiological roots is understandable in view of the limitations of neurological knowledge of his day. A major consequence has been the intellectually questionable – and increasingly unsupportable – practice among analysts to concretize brain functions into psychic entities. Starting with Freud himself, psychoanalytic discourse has been cast in the grammar of anthropomorphic metaphor, abounding in terms such as: *the* Id, *the S*uperego, t*he E*go, *the* self – all struggling on an intrapsychic battleground within "*the* unconscious". These concretizations can be comparable to a theological system incorporating immaterial vectoring entities in unremitting conflict with one another—unseen inner *dybbuks* flaunting the banners of instinctual reward and punitive consequence, polarized forces representing mature versus destructive behaviors. This polarized world view paradoxically reflects a type of regression to pre-Enlightenment medieval ontologies contrary to Freud's embrace of scientific thinking. An increasing tide of neuroscientific research comprehends these intrapsychic phenomena as functions rather than entities, as ever-changing, connecting, and parallel processing neuronal networks within the brain's assemblage of billions of neurons and trillions of synapses (LeDoux 2004). The paramount and ultimate vector of biological existence is not "instinctual" gratification, but propagative survival, according to Darwin (1869) and Dawkins (1976).

While the use of metaphor is unavoidable in any attempt to convey understanding of events in the world, descriptions of brain-based behavior are better employed by using verbal and adverbial metaphor, rather than resorting to nouns and adjectives. An example is the use of the word"selfing", referring to recursive neuronal circuitry (Edelman 1992) rather than "the self" (Brickman 2008 in press). This grammatical point is less trivial than it may seem, as neurodarwinian impacts on psychoanalytic thought will be illustrated below.

For close to 100 years, psychoanalytic theory has devolved into a variety of competing thought collectives, comparable to competing theories in anthropology, social psychology, and linguistics. While not promising total ideological integration, recent studies in attachment theory and neuroscience have fostered an increasingly discernible drift toward intersubjective, rather than positivistic and mechanistic, thinking. As mentioned above, a major historical figure in psychoanalysis, John Bowlby (1969), has compellingly introduced Darwinian and ecological perspectives on child development and sociality into the field. Accordingly, an anti-Cartesian view of the mind as embodied and rooted in the long history of natural selection of our social species is coming into greater focus. Many psychoanalysts, however, continue to agree with Freud (who obviously was not consistent) that our science is only verifiable through the intensive case study method and should not be judged by empirical perspectives that require non-treated controls and deliberately varied, and frequently unethical, alternative treatment techniques. This was the same Sigmund Freud who later in his career defined the *Weltanschauung* of psychoanalysis as identical to the world view of science in general (Freud 1933).

Nevertheless, recent advances in cognitive and affective neuroscience, accompanied by research in molecular neurobiology and electronic imaging, have contributed to increasing biologization of psychoanalytic theories of development and psychopathogenesis. If psychoanalysis is increasingly, if ponderously, approximating itself with biology, the principles of Darwinian natural selection of behavioral phenotype must inevitably apply. Likewise, since sociality is the midwife of cultural influences on individual behavior [Fiske 1992, Cosmides & Tooby 2005}, a more thorough familiarity with the social sciences has begun to be implanted into psychoanalytic understandings. It is in the spirit of such an accommodationist stance, with postulated connections to both social and neural science, that the view of psychoanalytic theories of pathogenesis and cure can be reconsidered in terms of a continuum of alloregulatory and succorant behaviors. Empirical studies of psychoanalytic theory and practice, however difficult to implement, would be a desirable outcome of such efforts.

Contributions of attachment theory and relational learning theory

In the basically asymmetrical analytically informed therapeutic relationship, the therapist does not promote himself as the authoritative arbiter of “the truth” of the patient’s inner representational world. A state of open receptivity encourages warded-off psycho-emotional conflicts to emerge from within the interactive process itself. This praxis reflects a more specific concern with the relational aspects of human behavior than was the case in analytic technique from the time of Freud until near the end of the 20th Century, when “making the unconscious conscious” was a guiding principle.

Reports of the conceptual foundations and technical implications of this ideological shift are to be found, for example, in the research of Fonagy and his associates at University College London in attachment theory and reflective thinking (2002). Also, Stern and the Boston Process of Change Group (1998), as mentioned above, have thoroughly studied the key role in analytic therapy of procedural learning and non-verbal aspects of interaction within a relational ambience in the consulting room. These theories propose that attachment styles developed in early childhood inform adult relationships including those occurring in the consultation room, and that a non-authoritative co-subjective therapeutic process not relying exclusively on linguistic interaction can bring about modifications in behavioral patterns through new implicit learning.

As mentioned above, increased verbal insight into these processes, while helpful at the cognitive level, takes second place to the acquisition of new procedural knowledge. In contemporary American lingo, it is a matter of not only "talking the talk", but more importantly, "walking the walk". These new findings rely on recent neuroscientific confirmations of continued synaptic plasticity in the adult brain (Braun & Bogerts 2001, (Ansermet & Magistretti 2007). Interestingly, these recent perspectives on procedural learning do not necessarily invalidate the effectiveness of more conventional analytic treatment based on earlier theoretical models. The argument of relational/intersubjective analysts is that, even in those clinicians guided by earlier formulations with their rich vocabulary of anthropomorphic metaphorizing, the "bottom line" effectiveness of psychodynamic therapies seems better explained by the neurodarwinian concepts of procedural learning, including the detoxification of self-defeating attachment styles.

The impact of evolutionary biological thinking on psychoanalytic perspectives

Carrying forward the earlier discussion of the grammar of analytic concepts of unconscious mentation, recent advances in neuro-psychoanalysis suggest a selective advantage of good-enough innate anticipatory neural networks that prepare for the exigencies of human social life. Faulty or self-defeating preparative neural networks and consequent behaviors can seriously disadvantage an individual's social, physical, and genomic survival in many ways. In like manner, a fragmented or totally absent life narrative, even when unconsciously held, deprives an individual of a sense of a robust life trajectory, thereby generating a depressive and anxiety-laden *Weltanschauung.*

A new conceptual triad of psychology, sociality, and evolutionary neurobiology has been increasingly influential in psychoanalytic theory and technique. This conceptual triad is illustrated, for example, by the conclusions of Fonagy and his co-investigators (2001) that the capacity to attune oneself to the intentional states of conspecifics, also known as theory of mind or mentalization, is enhanced significantly by psychoanalytic therapy, and may in fact be the gold standard of therapeutic efficacy. This is further discussed below.

While anticipatory neural networks would seem to be worthy candidates for natural selection, theory of mind has undoubtedly been naturally selected as an advantageous mental process furthering personal and genomic survival. Its universal presence in *Homo sapiens* seems to have been enhanced by the acquisition of language. In turn, the mixed blessing to our species of language acquisition allows for more effective communication as well as more effective deception of one’s intentions. Darwin’s “The Expression of Emotions in Animals and Man” (1872) was a splendid description of the array of vocal, facial, gestural, postural, and motoric phenomena in all animals that reflect the perception as well as the response to perceived intentions of conspecifics and others. Many of these maneuvers among non-human animals are deceptive; their persistence indicates their contributions to the organisms’ survival through natural selection.

Self deceptive inner conversations, often supported by verbalized beliefs, can be highlighted as a significant factor in a wide range of human behaviors beyond those considered neurotic. For example, the confident skin glow and common belief in the blessings of pregnancy in the expectant young mother-to-be protectively ignore the desperate zero-sum arms race in her uterus between herself and her parasitic fetus The skin glow itself may be an effect of increased blood pressure in the pregnant woman – a neurocirculatory campaign in her unknowing struggle. In extreme cases this internal struggle can lead to fetal death through starvation on one side, or, through eclampsia, to maternal cardiovascular damage, or death through uncontrollable hypertension in the mother.

Linguistic considerations in clinical interaction: toward reconciling three theories

In humans, the self-deceptive sector of language has evolved to prevent the inadvertent communication of self-doubt – a form of undercutting one’s effectiveness in social exchange. In ordinary social intercourse, subjects and their relational others rely on language to convey intention and response. In such cases, the inevitable, generally more subtle, non-verbal cues inconsistent with what is actually said and heard, are more or less ignored. This can serve the survival ends of the subject – as long as the intentional counter-currents remain concealed by the spoken word.

The work of the language philosopher J.L. Austin in *How to Do Things with Words* (1975) focuses on his supposition that language can be most usefully understood as action rather than as communication alone. Hence, he regards the behavioral role of spoken language as “*speech acts”*, thereby distinguishing the *performative* from the *constative* aspects of verbal utterances. Generally speaking, a constative speech act is a relatively simple one which can be confirmed or negated as a fact, exemplified by a statement such as “It’s raining outside”. One to whom this remark is addressed would tend to either agree or disagree.

A *performative* speech act, always more complex, conveys meaning rather than simple observation. It can reflect various facets of intentionality, including a conscious or unconscious intent to influence the hearer’s attitude or behavior, or what the speaker perceives as the hearer’s intentional stance or behavior.

To the extent that speech act theory can serve as an evolved evolutionary foundation suitable for reconciliation with psychoanalytic thought, I suggest that the predominantly verbal track of psychoanalytically-informed psychotherapy, requiring the therapist to decode the meaning-saturated *metalanguage* of the patient’s utterances, potentially illuminates the understanding of performative speech acts. Psychoanalytic therapists are crucially concerned with intentionality in their patients and in themselves. Non-verbal cues have been empirically shown to be major portals of access to the structures and functions of meaning underlying even the most seemingly trivial utterances – even by therapists themselves – provided self-reflective attunement is in play. Austin’s speech act theory, then, is reconcilable with psychoanalytic theory, via a common connection with the evolutionary biologist Robert Triver’s (2002 pp. 271-293) theory of the adaptational functions of deception and self-deception.

In psychodynamically-informed psychotherapeutic exchanges, the therapist must be trained and experienced in picking up non-verbal cues, thereby enabling perception of a more authentic inner narrative than the tale the patient often defensively yet unwittingly tells others and himself. The tool kit of an effective dynamic therapist is enhanced by a capacity for applying linguistic and mentalization theory. In fact the prominent contemporary psychoanalyst, Peter Fonagy, cited above, and his co-investigators, view psychoanalysis and its dynamic offshoots as most successful to the extent that it enhances the patient’s theory of mind by means of “mentalized reflexivity” (Fonagy et al 2002 pp.435-468) This enhancement of theory of mind allows the patient to come to terms more effectively with his own emotional states as well as those of others.. This theory of psychopathogenesis and cure, substantially based on attachment developmental theory, is an impressive example of Darwinian neuro-psychoanalytic thought.

The narrative nature of the human inner world

The work of Llinas and Pare (1998) has demonstrated that no animal with a cerebral cortex has direct and unfiltered sensory access to its physical and social surrounds. Over millions of years, brains have developed a survival-oriented representational function which has co-evolved with the increasing encephalization and corticalization of the brain. At the pre-reptilian and reptilian levels, interaction with the physical and biological surrounds requires no inner representation. The largely reflexive limbic system (amygdala and hippocampus) activities, such as feeding, fighting, freezing, fleeing, or mating, require no cerebral filtering. The increasing complexity of life in social mammals has required the evolution of more complex cortical and subcortical neuronal assemblies for humans to subordinate the foundational limbic system behavioral tendencies with a huge welter of activational and inhibitory neural circuits, synapses and inner world representations. These neural phenomena seem to organize human subjectivity in terms of variations on a self-postulated narrative theme. Much of the psychoanalytic literature portrays these narrative constructs as ongoing unspoken yet influential ‘conversations’ between a putative self representation and representations of formative others from early in the individual’s life.

The survival value of these inner conversations would require their adaptational suitabilty to interpret the world in closer correspondence to what is real – or, at least, to what is confirmed by valued others as real. In virtual competition with these adaptational inner representations, a persistent unconscious reservoir of conflictual neural processes, conventionally known as “the unconscious”, serves as an index of emotionally-drenched memories and their complex neuropsychological innervative connections throughout the brain. The inner representations of the world influenced by these assemblies compete for applicability as models for “here and now” experience. Much of human behavior, especially in the neurotic band of the spectrum, constitutes what Freud and his followers have called compromise formations – symptoms and actions reflecting, neuropsychologically speaking, a balance between excitatory and inhibitory neural circuits. Again, it is important to add that the neural processes underlying these behaviors are yet to be clearly mapped through neuroimagery studies.

In a manner similar to the body’s immune system, neurodynamic systems of conflictual unconscious processing have evolved to segregate noxious memories from conscious declarative and autobiographical memory and to attempt self-healing behaviors. The motivational sources of behaviors generated largely by conflict-derived unconscious functioning are most readily accessed through interpersonal dialogue with trusted others. Psychoanalysts and psychodynamic therapists hope to exemplify such trusted others. Often, successful psychotherapy results can pivot on session-to-session joint resolution of therapists' occasional failures to be trustworthy.

This shimmering, intricately and multiply interconnecting neural reservoir (metaphors fail here), this cerebral immune system, propagates a host of behavioral devices such as denial (largely employed to prevent confessions and actions that would be adverse to the survival of the individual and his genome), self deception, splitting and isolation, projection, intellectualization, dreaming, creative artistic activity, and compensatory symptom formation. These "mental mechanisms" are not always considered psychopathological; at times, for example, denial and self-deception can be advantageous to fitness. The behavioral expressions of these devices are the building blocks of compromise formation discussed above, with the possible exception of many behaviors and inner mental states induced by addictive practices.

The adaptational role of conflictual unconscious processing

A neurodarwinian perspective, therefore, suggests the evolutionary survivability of conflict-derived unconscious functioning as an adaptive functional tool, a neuro-psychological immune system conceivably evolved to manage individual suffering in a social world conceived at times as overwhelming. Dreams, fantasies, "unthought" ideas are among the self-healing activities of that conflict-laden domain of unconscious mentation. Borrowing from naval parlance, the self-healing aims of such an adaptive tool suggests the 'sick bay' function of a ship at sea, where medical personnel promote the goals of the voyage by attending to the injuries of officers and crew so they may remain on partial or full duty until fully healed. A limping, bandaged or depressed member of the ship's company remaining in the succorant care of sick bay personnel is not a critical deterrent to the vessel's continued voyage. Absent an evolved neurobiological capacity for processing the effects of trauma, insecure attachment, abandonment experiences and other hurtful events during early development, destructive and self-destructive behaviors would abound, to the detriment of individual and group survival. Further research is clearly necessary to identify a more detailed evolutionary rationale for this prime domain of psychoanalytic interest.

Conclusion

Beginning with a re-interpretation of Descartes' famous *Cogito,* I argue that the form of contemplative thinking the philosopher had in mind was self-reflective rather than transitive in nature.. Furthermore, self-reflective thinking, as an evolved aspect of theory of mind, appears to be uniquely human, and characterizes psychoanalytically-informed psychotherapy. But a non-Cartesian, thoroughly embodied, psychoanalytic view of psychological and emotional dysfunction is not limited to thought processes when it is informed by evolutionary neurobiology and psychology. It allows us to conceive of psychodynamic therapy as enhancing theory of mind, or mentalization in social contexts. It also allows us to understand the widespread practice of self-deception, and the roots in a continuum of succorant animal behaviors of all forms of psychotherapy. A major implication of such a more contemporary psychoanalytic view is that more research is needed to reveal the selective value of unconscious neuro-psychological processing of intrapsychic conflict. Additional research should also attempt to illuminate the more immediate adaptational function of psychotherapeutic processes based on a reconciliation of Darwinian, neurobiological, and depth psychological perspectives which the author identifies as *Darwinian neuro-psychoanalysis*.

In contrast to mentation in non-human animals, two uniquely human roles of embodied conflict-derived unconscious functioning are evolutionarily understandable: a) as a naturally selected type of self-deception to keep oneself unaware of what is felt to be socially objectionable or dangerous in one's inner representational world, thereby impeding human conspecifics from mentalizing one's hidden intentions; and b) as a self-healing module of the human organism evolved to correct maladaptive predictions, potentially enhanced by the healing effects of the self-reflective, and basically succorant alloregulative *meditations á deux* entailed in psychoanalytically informed psychotherapy.

While the possibilities and problems of addressing these formulations through empirical research are akin to the problems in using observations of present-day hunter gatherer life to scientifically confirm or falsify theories of the nature of human life during ancestral times, a truly scientific theory of conflict-derived unconscious functioning, while being explored at present, is yet to be successfully accomplished (see Luyten et al 1997).

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CHAPTER EIGHT

WHY THE HUMAN BRAIN IS NOT AN ENLARGED CHIMPANZEE BRAIN

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Abstract: Following Darwin, many comparative psychologists assume that the human mind is a kind of ape mind, differing only in degree from the extant apes – we call this the mental continuity assumption. However, the continuity principle in evolutionary theory does not posit continuity between extant closely related species, but between extant species and their extinct ancestors. Thus, it is possible that some human cognitive capacities have no parallels in extant apes, but that they emerged in extinct hominid species after the human-chimpanzee divergence. Our examination of the case of social cognition from an archaeological and comparative psychological perspective suggests that the human brain is not simply an enlarged chimpanzee brain. Instead, natural selection seems to have favoured a different social cognition in both species.

Introduction

Among comparative psychologists, the belief prevails that the human mind is a kind of ape mind, differing only in degree from the extant apes. An influential formulation of this *mental continuity assumption* comes from Darwin, who probably wrote this under the influence of Thomas Huxley (1871: 105):

> “Nevertheless the difference in mind between man and the higher animals, great as it is, is certainly one of degree and not of kind. We have seen that the senses and intuitions, the various emotions and faculties, such as love, memory, attention, curiosity, imitation, reason, &c., of which man boasts, may be found in an incipient, or even sometimes in a well-developed condition, in the lower animals.”

As a consequence, most investigations of nonhuman primate cognition are conducted with an anthropocentric agenda: do chimpanzees seek causal explanations (Povinelli & Dunphy-Lelii, 2001), do they have cultures similar to ours (Whiten et al., 1999), do they possess a theory of mind (Call & Tomasello, 1999)?

The theory of natural selection compels us to see the history of life like a branching tree rather than a scale. Accepting that there is a diversity of minds, and not a single scale of progressive cognitive development raises several questions. If the human mind is but one evolutionary outcome among many, why then this outcome, and not some other? What cognitive capacities have been selected for during human evolution? Tackling such questions may help us gain insight into how the human mind works, and also promises a better understanding of other animal minds, such as that of the chimpanzee.

The mental continuity assumption is currently a progressive research programme, because it generates a wealth of empirical findings. Yet it is plagued by anomalies. For example, humans behave altruistically, even if it poses a cost to them, yet Silk et al. (2005) found that chimpanzees do not help others, even at no cost to themselves. In the history of science we find two ways of dealing with anomalies. One is to keep on designing experiments, in this case until chimpanzees perform in accordance with the mental continuity assumption, like Warnecken and Tomasello (2006) who set up an experiment in which *infant* chimpanzees spontaneously helped *human* trainers. A second option, presented in this paper, is to treat these anomalies as evidence of fundamental differences between human and ape cognition and to abandon the mental continuity assumption. We examine neuro-scientific, ecological, and developmental psychological evidence that speaks against the widely held belief that the human brain is an enlarged chimpanzee brain. We trace diverging ecological and social contexts in hominid and chimpanzee evolution after their split about 6 million years ago, and show that these have yielded unique social cognitive adaptations in each species.

Neuro-scientific Evidence Against the Mental Continuity Assumption

One must keep in mind that the continuity principle does not apply to extant related species, but to species and their extinct ancestors (see also Pinker, 1994). Since we evolved in differing ecological contexts, it is a contingent fact that some human cognitive capacities have no parallel in extant apes, but that they emerged in extinct hominid species, after the hominid-chimpanzee divergence. Even on a very short timescale, selection can craft cognitive specializations as a result of unique, species-specific pressures. Take the extreme case of differing social cognition in dogs and wolves. Dogs are domestic animals, living in the human cultural niche. They developed adaptations for social interaction with humans, such as understanding pointing gestures and making eye contact (Miklósi et al., 2003). Wolves lack these capacities, although genetic evidence shows that dogs have diverged only 15,000 years ago and genetically differ by only about 0.15 % from contemporary wolves (Savolainen et al., 2002). Thus, the estimated divergence time of 6 million years between humans and chimpanzees (Stone et al., 2002) is in principle long enough to create cognitive specializations in each. Indeed, studies of gene expression in human and chimpanzee brains show that certain brain areas and thus, cognitive capacities have been under divergent evolutionary pressures in both species (Oldham et al., 2006; Cacéres et al., 2007).

Comparative neuro-anatomical studies (e.g., Barton et al., 1995) show that primate brains do not only differ in size, but also in internal organization and structure. Interestingly, this organization reflects a species' ecology and social structure, rather than its cladistic relatedness. For example, woolly monkeys (*Lagothrix poeppigii*), a species of New World monkeys, have an energy-rich diet consisting mainly of fruits and insects. As a result, the internal organization of their brain looks very similar to that of chimpanzees and differs considerably from that of other closer related New World monkeys (De Winter & Oxnard, 2001). Rilling and Insel (1999) compared brains of 44 primate species using magnetic resonance imaging. Their research indicates that the human brain is not simply an enlarged ape brain: some areas have grown allometrically in humans, such as the prefrontal and temporal cortices, which are involved in language and theory of mind, whereas others, such as the cerebellum, which deals with locomotion, are reduced compared to those of orang-utans and gibbons. Interestingly, the corpus callosum, which connects areas of similar function between the hemispheres, is reduced in humans compared to other apes. This reduced connectivity allows for greater autonomy and divergent evolution of different brain regions which may have enabled left-lateralization of cognitive functions such as language and tool-use in humans (Hopkins & Rilling, 2000).

As a matter of empirical fact then, the human brain does not appear to be an enlarged chimpanzee brain. What selective pressures are responsible for this divergent cognitive evolution? Empirical studies of brain size and organization in birds (Burish et al., 2004) and ungulates (Shultz & Dunbar, 2006) indicate that both ecology and social structure are important factors in cognitive evolution. In the next section, we apply this ecological approach to hominid and chimpanzee cognitive evolution, by sketching the different palaeo-ecologies of these lineages since their divergence. Later we will look at the comparative psychological literature for evidence of cognitive specializations that might reflect these differing selective pressures, focusing on social cognition.

Ecological and Social Selective Pressures During Hominid and Chimpanzee Brain Evolution

Like all animals, the extant great apes exhibit dietary adaptations that reflect past selective pressures. During the early Miocene (23-15 million years ago), apes reached their greatest level of diversity, filling a wide range of sympatric niches. Fossil hominoid dentition and gut content (Franzen & Wilde, 2003) indicate that their diet consisted exclusively of vegetable foods. By the late Miocene (11.6-5.3 million years ago) however, they came under pressure from both climate change and competition by the Old World monkeys. The few ape species that survived this competitive sweep did so by adopting unusual ecological niches (Milton, 1999).

Gorillas and orang-utans developed a larger body size and turned to lower quality plant foods, such as mature leaves and bark, thus avoiding intense competition with monkeys. Chimpanzees became dietary specialists of ripe fruits, nuts, young leaves, insects and small vertebrates, which contain higher levels of calories and protein. Because high-quality food is scarce, competition for food is intense. As a result, female chimpanzees with dependent offspring are forced to live and forage solitarily, because their slowness puts them at a competitive disadvantage (Hrdy, 2005). An exception to this general rule is *Pan troglodytes verus* (a West-African chimpanzee subspecies), which exploits locally abundant species of nuts with stone hammers and anvils (Yamakoshi, 2001). Yet even these females compete for food and form linear dominance hierarchies (Wittig & Boesch, 2003). Male chimpanzees cooperate to defend communal ranges, groom, and engage in coalition formation against dominant individuals. However, there is also intense competition between males. Even among maternal brothers, who form the backbone of chimpanzee social groups, meat-sharing is rare (Langergraber et al., 2007). Bonobos, who live in the more food-rich Central African rain forests, rely on fruits, leaves and terrestrial herbaceous vegetation (flowers, young leaves and pith), which is a locally stable and widely available source of protein (Rafert & Vineberg, 1997). This probably enables bonobo females to form cooperative alliances. Cooperation among male bonobos is restricted to periods of relative fruit abundance (White, 1998). Whereas selection has enhanced sociality in chimpanzee males, it seems to have favoured increased sociality in bonobo females. Humans are unique among primates in their obligatory reliance on tools to extract food. Analyses of diets of contemporary hunter-gatherer groups (Kaplan et al., 2000) show that humans prefer food that is hard to obtain – through hunting or extraction – but that is high in energy and nutritive value. Less than 10 % of all food types they exploit are relatively calorie-low vegetable foods that are easy to obtain (fruits, leafy vegetables). In contrast, the bulk of chimpanzee diets consists of easy to obtain food. From this brief survey, it becomes apparent that the apes each occupy a unique ecological niche. These dietary niches also influence social organization. In order to understand how human cognition differs from that of other apes, it is important to reconstruct the environment in which most of the cognitive evolution of these species took place.

Modelling Past Selective Pressures on Cognitive Evolution

Marine sediment sequences provide evidence for stepwise increases in East-African aridity during the last 8 million years (deMenocal, 2004). This dryness was caused both by a global cooling trend, and by the formation of the Rift valley, which blocked East-Africa from the rains from the Atlantic Ocean (Pickford, 1990). The aridity forced early hominids to extend their daily foraging range, favouring bipedal locomotion, which is more energy-efficient than all other known forms of primate terrestrial locomotion (Leonard & Robertson, 1997).

Bipedalism emerged about 5.2 million years ago (Haile-Selassie, 2001), which is almost immediately after the split between hominids and chimpanzees. It had unexpected consequences for early hominid social interaction, because it made female cooperation practically inevitable. The bipedal ape cannot look at her own offspring while giving birth, and thus cannot assist her young, such as removing mucus from its face or loosening a suffocating umbilical cord. Nonhuman apes habitually help their own offspring in this way, but bipedalism requires assistance (Rosenberg & Trevathan, 2002). In all human cultures, women in labour receive help. Whereas female chimpanzees do not form alliances, female *Ardipithecus* as early as 5.2 million years ago required help during birth. Female alliances were further promoted as early *Homo* developed childhood, a new lifecycle that required alloparenting by other females (Bogin & Smith, 1996). Once hominids developed a brain size that was markedly larger than that of chimpanzees, which occurred about 2 million years ago, they were forced to wean their infants earlier to meet the nutritional demands of the rapidly growing brain. Humans have the shortest lactation period of all apes, weaning infants at about 30 months, whereas chimpanzees are breastfed for about 62.8 months on average, and orang-utan infants are lactated about 7 to 9 years (Kennedy 2005). Shorter lactation times result in shorter interbirth-intervals: traditional hunter-gatherers have interbirth-intervals of about 3 to 4 years. However, human children need intensive care until they are 6 or 7. This places heavy demands on their mothers, who often have to take care of several dependent children at the same time. In most pre-industrial societies, women solve this problem by developing extensive networks of alloparenting. In some cases, such as the Aka pygmies, childcare networks comprise over 10 individuals including several nonkin members (Ivey, 2000). Therefore, it seems plausible that early hominids from about 2 million years on showed greater cooperation between females than chimpanzees, perhaps on a par with what we observe in bonobos today.

A second step towards increasing aridity in East-Africa took place around 2.8-2.5 million years ago (deMenocal, 2004), leading to the disappearance of the remaining tropical rainforest (Bonnefille, 1995). Because fruit and young leaves became scarce and seasonally unavailable, hominids were pushed to exploit alternative ecological niches. One clade, early *Homo*, began to rely on meat to compensate for the seasonal unavailability of rich plant food sources. Examinations of cutmarks on fossil bones and traces of wear on stone tools indicate that early hominids obtained most or all of the meat in their diet through scavenging: they cut meat with sharp flakes, and crushed bones to obtain the marrow by using hammer stones (Capaldo, 1997). At least three sabre-tooth genera inhabited Pliocene Eastern Africa. They were relatively small felids with powerful front paws and teeth, which enabled them to kill prey far too large to satisfy their own needs (Lewis, 1997). These partly defleshed carcasses provided the hominids with a stable and reliable food source. Because hyenas, their only competitors, are dangerous gregarious animals, it seems plausible that hominid males cooperated to defend the carcasses, as analyses of tooth marks and cutmarks on bones demonstrate that hominids got to the carcasses before the hyenas (Domínguez-Rodrigo & Barba, 2006). This suggests that male hominid coalitions were at least on a par with those of male chimpanzees.

The evolution of the *Pan* lineages is less well-documented than that of the hominids, because chimpanzees mainly evolved in wooded West- and

Central-Africa, where fossil preservation is worse than in dry East-Africa. Only teeth belonging to one fossil species of the genus *Pan* dating to circa 545,000 years ago have been recovered (McBrearty & Jablonski, 2005). However, it is interesting to note that according to mtDNA studies (Stone et al., 2002), the split between *Pan troglodytes* and *Pan paniscus* (bonobo) occurred about 1.8 million years ago, which coincides with an extreme global cooling and drying event that also gave rise to *Homo ergaster* in East-Africa. Given that East-Africa experienced more climatological instability than West- and Central-Africa, it seems plausible to assume that chimpanzees and bonobos occupy their current niches for at least 1.8 million years.

Differing Social Cognition in Humans and Chimpanzees

These differing ecological conditions resulted in diverging social cognitive adaptations in humans and chimpanzees. A striking difference is that chimpanzee cognition is more tuned to competition whereas that of humans is tuned to cooperation. Povinelli et al. (2002) found that chimpanzees seem oblivious to the attentional state of a person who helps them find food: they are as likely to beg food from a person who looks at them as from someone with a bucket over her head. However, they do better when they are placed in a competitive situation. They can effortlessly find a reward if the experimenter pretends to reach in vain for it, a gesture that looks quite similar to pointing (Hare & Tomasello, 2004) – apparently, once they see the experimenter as a competitor, they can solve the task. Experiments with conspecifics show similar findings. Chimpanzees have difficulties working together to pull a rope to obtain food that is out of reach (Melis et al., 2006). Bonobos outperform chimpanzees in cooperative tasks (Hare et al., 2007), presumably because they have a broader diet and thus are more tolerant.

A host of experiments (see e.g., Fehr & Rockenbach, 2004, for an overview) show that humans across cultures behave exceptionally altruistically; they help others even at some cost to themselves and they are prepared to help people they will never meet again. In our view, human altruism can be explained by the unique ecological conditions in which hominids evolved. As we have seen, they had access to an abundant food-source, scavenged meat and marrow, but obtaining and defending this food required extensive male cooperation. Moreover, hominid females became more social, because bipedalism necessitated assistance at birth, and alloparenting developed when childhood emerged as a new lifecycle.

Human social learning is characterized by a set of distinctive features, such as imitation, teaching and joint attention. Hunter-gatherer children depend on adult members of their community for food. Typically, girls become proficient gatherers during late adolescence, whereas men only become proficient hunters in their thirties (Kaplan et al., 2000). In contrast, chimpanzees acquire all tool-using traditions of their community during their first five years of life. Whereas humans learn mostly from peers and other members in the community, infant chimpanzees learn almost exclusively from their mothers. It is therefore not surprising that humans and chimpanzees differ in the way they acquire cultural behaviours. Laboratory and field studies have revealed a unique kind of social learning in chimpanzees, which Matsuzawa (2007) termed "education by master-apprenticeship". It is characterized as follows: the infant spends most of its time alone with its mother. It is highly motivated to acquire her behaviour. The mother, however, does not teach or provide any positive or negative feedback. In stark contrast to humans whose learning is based on triadic interactions – mother, infant and object – chimpanzees learn from dyadic interactions only: they observe their mothers' behaviour carefully, and this helps them to reconstruct the action for themselves. A detailed comparative study (Tomonaga et al., 2004) shows that chimpanzee and human development are similar during the first months of life: the infants of both species engage in dyadic interactions with their mothers, such as smiling and mutual gazing. However, at about nine months, human infants develop the ability to share their attention for a specific object *with* another person (Tomasello & Carpenter, 2007). This results in a referential triangle of infant, adult and the object upon which they share attention. Crucial for this is that the infant knows that it shares its attention for the object with someone else – it is thus aware of the mental state of the other. This "nine-month revolution" does not occur in chimpanzees. Tomonaga et al. (2004) failed to engage in triadic interactions with infant chimpanzees, despite trying for months. Cultural learning in chimpanzees thus differs fundamentally from that of humans. Tomasello and Rackozy (2003) have proposed that our ability to engage in triadic interactions makes cumulative cultural learning possible. We hypothesize that the technical skills required for making stone tools may have exerted intense selective pressures on human cognition to enable us to share attention over objects.

Even the oldest stone tools of about 2.7 million years old, the Oldowan technology, require extensive cultural learning. Only oblique angled strikes result in razor-sharp flakes with a typical conchoidal fracture pattern. Early *Homo* turned the core around while flaking – indicated by the multiple striking platforms – and chose the most efficient angles to strike the core (Roche et al., 1999). Both a chimpanzee (Kitahara-Frisch, 1993) and a bonobo (Schick et al., 1999) have been extensively tutored to learn how to make Oldowan type stone tools, but both failed to strike the cores at the correct angles, indicating that Oldowan technology is beyond their social learning skills. Next to this, good flakes are only obtained from cores with a dense, fine and even (isotropic) structure. Hominids transported raw materials several kilometres to the sites where they found and butchered the animal carcasses (Plummer et al., 1999). Even when they obtained cobbles from local sources, they were selective in the choice of their raw material: the earliest stone tools from Gona, Ethiopia, were made from locally scarce vitreous volcanic clasts, not from the locally abundant basalt, which is of lower quality and does not yield good flakes (Stout et al., 2005). This anticipatory behaviour in raw material selection has not been observed in extant nonhuman primates.

To facilitate sharing attention and cooperation, humans have evolved unique anatomical and neuropsychological adaptations. For example, the human eye shows a large white sclera on both sides of the iris. This makes it easy to follow our gaze direction. In contrast, all other primates have a pigmented sclera, which makes it difficult to follow their gaze (Kobayashi & Kohshima, 2001). All primates are good at following gaze direction. Yet, in their highly competitive world it is not always good to have others know what one is up to, especially not during competition for food – so it is advantageous to have a dark sclera which camouflages gaze direction. Human white sclera might actually have evolved to facilitate reading eye direction, thus augmenting the possibility to decipher intentions. Through triadic interactions, we still make objects part of our social world. Humans across cultures reason about objects in terms of their intended function (Bloom, 1996), even in cultures with a limited technology (German & Barrett, 2005). This intentional stance for artefacts is apparent in children as young as two years of age (Casler & Kelemen, 2007). It is a direct result of our ability to incorporate objects into triadic interactions: when considering an artefact, we can think about the intentions of the maker, such as the planned function of the object. This would not have been possible if humans, like chimpanzees, engaged in dyadic interactions only. It is therefore not surprising that there is currently no evidence for the intentional stance for artefacts in nonhuman primates.

Conclusion

Although the mental continuity assumption has generated an interesting body of empirical literature, our palaeo-ecological survey suggests that it is fundamentally flawed. If we concentrate too much on human cognition as *the* starting point of investigations of comparative cognition, we risk overlooking many cognitive specializations in other species. There is a real danger that we may never truly understand ape cognition: through the destruction of their natural habitats, most species are threatened with extinction; next to this, many western countries start restricting chimpanzee and bonobo research. Now is the time for comparative psychologists to abandon human cognition as the starting point of their investigations of nonhuman primate cognition, but rather to study the contexts in which these species have evolved. The case of social cognition shows that this approach could turn out to be at least as fruitful as the anthropocentric stance.

Acknowledgements

We wish to express our gratitude to members of the audience at the Human Mind-Human Kind Conference at Aarhus (15-18 August, 2007) for their helpful suggestions and comments. This research was partly funded by grant OZRBOF916 from the Free University of Brussels.

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