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Letters on Nature and Nurture

Onur Güntürkün

ABSTRACT

Humans and most other animals have a dual origin. One of these origins is defined by the genetic background that assembles brains, thereby implanting prewired expectations about the sensory and causal regularities of the world in which we are born. The second origin is the organized system of experiences that provides a plethora of feedback and instructions that slowly shape the brain into its final status. In humans, these experiences start especially early to modify the newborn brain and provide an unusually variable tapestry. For decades, scientists have tried to disentangle the impact of nature and nurture, and have proposed mental territories that are mostly governed by one or the other. Here, I argue that genetic predispositions and environmentally dependent learning processes interact continuously at every neural and mental entity, from cortical development to social customs. Not a single territory of our mind is outside the scope of this interaction.

PRELUDE

Scientific inquiries into the interaction of biology and culture usually study a certain developmental span, an important event, or a neural, affective, or cognitive system to set a stage on which the details of biocultural co-constructivism can be outlined. This approach necessarily takes a narrow focus but provides great depth and insight into the interactive mechanisms. This book provides many outstanding examples of this kind of approach. As fruitful as this strategy is, there is also the need for a further perspective showing that biology and culture not only interact at the selected focus area, but also at every single entity that constitutes the human mind. It is difficult to couch such a broad picture without being too long or too shallow. I have therefore tried to express this view by a letter exchange between

two fictive scientists, Hakan and Maxim, who attended the meeting on biocultural co-constructivism at Dölln-Schorfheide and who continue the debate they began there on the terrace. Hakan is leaning more toward the cultural side, whereas Maxim feels close to biology-driven arguments. Via their letter exchange, they explore the vast territory from genes to culture that is constantly co-constructed by nature and nurture.

THE DIALOGUE

Melun, August 22, 2003

Dear Maxim,

It was a great pleasure to meet you at the conference. After getting home, I had a long discussion with my wife, Meltem, about some of your arguments. She was impressed by your biology-prone reasoning and has now tried to convince me that the basic wiring programs of the brain proceed with little environmental feedback. After having Aylin (she is now 2 months old), all questions about the forces that shape the emergence of personality in our little daughter are obviously hotly debated between Meltem and me.

Although I must admit that you provided strong data on genetic determinism during the conference, I'm still reluctant to accept that they are able to explain most of the even basic details that make us human. For example, in passing, you said: "You aren't taught to see! You develop vision by yourself." I don't believe that, and I'm pretty confident that I have excellent arguments on my side. I think that the genetic program is far too limited to have a chance to determine the fate of the brain. It merely defines a few rules. The details of wiring depend on subsequent sensory input that shapes the nervous system into its adult form.

Let's start the most simple way - by counting genes in the human genome. Latest estimates from the Human Genome Project suggest that there might be 24,500 or even fewer protein-coding genes. This number is constantly dwindling from previous estimates of around 100,000. Yes, we meanwhile know that some genes code for more than one protein, but we also know that more than 3,000 genes of our limited gene number are probably pseudogenes, ones that code for nothing due to some aberration of their DNA. This lower estimate came as a shock to many scientists because counting genes was viewed as a way of quantifying genetic complexity. With far less than 30,000, the human gene count would be only a little bit greater than that of the simple roundworm *Caenorhabditis elegans*, which has about 20,000 genes. By the same token, humans appear only four times as complex as the bacterium *Pseudomonas aeruginosa* (Claverie, 2001). So, our gene content does not appear to be directly related to our intuitive perception of organismal complexity. But, the situation is even worse: the genome projects of animals such as dogs, cows, and chickens,

and others such as puffer fish, show a large overlap of sequences, with humans and chimpanzees sharing 98.8% of their DNA sequences (Pääbo, 2003). So, the genetic degrees of freedom to construct those aspects that make us specifically human are getting smaller and smaller (Chapter 4).

Now, let us as an extreme argument assume that all human genes exclusively code for our brain - an assumption that is of course vastly exaggerated (estimates assume about half of our genome to be coding for the brain). The human neocortex hosts about 21×10^9 neurons (Pakkenberg & Gundersen, 1997). This is easily surpassed by the number of granular cells in our cerebellum, 11×10^{10} (Andersen, Gundersen, & Pakkenberg, 2003). If we only concentrate on neocortical neurons and use rather conservative estimates of the number of synapses per cell, we may assume that we have more than 20×10^{13} synapses in our cortex (Schüz & Palm, 1989). Thus, the gene-to-synapse relation is about 1:1,000,000,000 - and that's only for neocortex.

In school, I learned the saying of Pythagoras that numbers set a limit to the limitless and that they constitute the true nature of things. According to this logic, these simple calculations show that it is beyond the possibilities of the genome to control the detailed wirings of our brain. The only thing our genome can do is to define some rules and then lean back to let life mold the brain into its final shape. Therefore, my friend, we have to learn to see. We are blind without nurture, and we go on shaping our brain through each of our mental abilities, from mere perceiving to reading and thinking (Chapter 8). I will try to convince you by bravely stepping into your own turf: I now talk about the ontogeny of seeing.

As you know, preventing mammals from seeing after birth for several months renders them largely blind. Our visual system does not have the capacity to wire itself in a functional way without meaningful (patterned) input (Chapter 3). Just a few hours of seeing can, however, outweigh or protect against much longer periods of deprivation and permits the development of normal visual acuity in both eyes (Mitchell, Kind, Sengpiel, & Murphy, 2003). This seems to be, by the way, different for insects. Praying mantis that use stereoscopic vision to strike their prey do not need binocular experience to integrate the input of both eyes (Mathis, Eschbach, & Rossel, 1992). Thus, the complexity of an organism (I simply assume that we are more complex than the praying mantis; as you know, I'm hopelessly anthropocentric) determines the degree to which instructions from outside the organism are needed to wire the brain. Providing kittens with a striped environment of only one orientation tunes their visual system and subsequently their behavioral repertoire to this orientation only (Blakemore & Cooper, 1970). This need for an outside "instructor" is so important that, in mammals, the outside world is imported to prenatal life by synchronous bursts of retinal activity, creating virtual patterns to instruct the developing embryonic visual system (Meister, Wong, Baylor, & Shatz, 1991). This

whole field has meanwhile moved to experiments where sensory systems are rewired such that they synapse in the territory of other modalities. It can be shown that they are functional in their new destiny; thus, animals start seeing with their auditory system (Chapter 5). The reverse - superior hearing and language processing within areas outside the classic auditory system - can be shown in congenitally blind subjects (Röder et al., 1999; Chapter 6).

So, what do these stories mean? My conclusion is that during biological evolution, the project to construct a human (or any other complex organism) was faced with the serious bottleneck of a genetic code that was too scarce to be useful for a true genetic determinism of the brain. Therefore, genetic codes had to be used to determine a rather small set of rules that subsequently guide the ontogeny of the nervous system by exploiting the regularities of the sensory input. As a result, environmental instructions creep into our brains very early and at every neural level to shape its structure. By this mechanism, we are adapted to the very specific world in which we live and we are tuned to the regularities that we experience. Yes, we have to learn to see. Our brains are instructed and wired by the world around us. It was important for me to clarify this matter. I'd be delighted to hear what you think.

Hakan

Odense, September 11, 2003

Dear Hakan,

Yes, you are right that experience-dependent factors play an important role in shaping the juvenile brain. You are also probably right that I underestimate some of their impact. But I guess that you also underestimate the power of nature. As you will see, genetic factors are far more important than you assume.

First, you cited Blakemore and Cooper (1970) to underline your point that environmental information is used by the juvenile visual system to tune its orientation properties. This classic study has been meanwhile repeated with modern techniques and shows some very interesting additional facts (Sengpiel, Stawinski, & Bonhoeffer, 1999). If the visual cortex of kittens reared in a striped environment is analyzed using optical imaging, it is indeed evident that twice as much surface area is devoted to the experienced orientation as compared with the orthogonal one. However, the analysis also shows the existence of many neurons responding to orientations that were never seen by the kitten. Cortical orientation maps are therefore remarkably rigid in the sense that orientations that were never experienced by the animal occupy a relatively large portion of the cortical territory. In addition, other studies show that orientation-selective neurons are present within the visual cortex of optically deprived young kittens at the time of natural eye opening. These animals evinced quite normal maps

of orientation preference. In light of this evidence, it seems unlikely that the role of experience is to give a *tabula rasa* its final shape. Instead, visual experience seems to have an instructive role, whereby only those neurons whose initial (and thus genetically prewired) response range include the specific orientation seen after eye opening shift their preferences toward this experienced orientation. Obviously, there is a considerable intrinsic component in determining the layout of orientation preference maps. Environmental factors can modify these properties to some extent, but they do not create them.

This conclusion fits perfectly into the frame of newer studies that analyze the properties of the brain before experience begins. For instance, ocular dominance columns of the visual cortex are present in ferrets before visual experience begins and do not even require the presence of eyes for their initial establishment (Crowley & Katz, 1999). Although there is no dispute that activity-dependent processes are able to shape the system (this activity can be endogenous and therefore not necessarily externally driven) and that these processes are often necessary to stabilize a certain pattern, your assumption that "environmental instructions creep into our brain very early and at every neural level to shape its structure" is certainly misleading: the system already starts with a quite sophisticated initial shape.

In addition, our new understanding of plasticity in the brains of adult individuals shows that the principles of ontogenetic neural alterations according to environmental stimuli proceed in a similar way (Chapter 14). Even neurogenesis, once believed to be a hallmark of very young brains, is now known to also characterize the adult brain and possibly to continue until the end of life (Chapter 4).

There is also good evidence that the initial parcellation of cortex is regulated by molecular determinants that are independent of external influences and thus intrinsic to the developing cortex. Even factors that regulate structural borders and later cortical connectivity seem to be determined at an embryonic time point before the arrival of thalamic axons. Thus, genes that control the initial arealization of the neocortex also affect the whole connectivity of the system (Sur & Leamey, 2001).

Now, I come back to your argument that gene number is simply insufficient to code for wiring details. This view completely underestimates the power exerted by local molecular factors, which are able to pattern the brain. It is likely that you don't need too much genetic determinism to set up sufficient molecular rules to let the developing neurons find their own way. For example, cadherins (a group of cell adhesion molecules) provide a local code that regulates the binding of functional neural structures distributed across the embryonic modules. These modules represent histogenetic fields in which neurons are born and aggregate in distinct cell groups. Different subsets of these aggregates become

selectively connected by nerve fiber tracts and, finally, by synapses, thus forming the neural circuits of the functional systems in the central nervous system (CNS). Cadherin-mediated adhesive specificity may thus provide a molecular code for early embryonic CNS regionalization, from major embryonic subdivisions down to the level of individual synapses (Redies, 2000).

There is one more point where innateness strikes back, and that's with regard to time. I argue that the orchestration of the time-dependent influence of experience is under genetic control. To make this point clear, I briefly remind you of the mechanisms that guide imprinting. When young chicks are exposed to a visually conspicuous object, they approach it, learn its characteristics, and form a social attachment to it. In natural conditions, the object is usually the hen, but it need not to be; a wide range of objects will do, although those that resemble a hen are more effective than others. This latter point shows that a predisposition already exists but can be overridden by experience. Imprinting in chicks narrows the range of objects the animal will approach. Given a choice between a stimulus to which it was exposed, say, a rotating red box, and a different object like a rotating blue cylinder, a chick will prefer the training stimulus and will actively avoid the blue cylinder, which it has not previously seen. The sensitive period is normally rather short but can be extended if no object for imprinting occurs. Thus, the young organism is experience expectant, but its genes define a sharp time window for experience to occur. Even more interesting is that an imprinting episode early in life is able to influence sexual preferences during adolescence (Bischof, 1983). You might argue that imprinting is a mechanism that occurs only in a few species and has no relation to humans. I see it differently. Imprinting is just the extreme form of a genetically determined time window for certain experiences. All vocal learners (including us) operate with sensitive periods (White, 2001). I will send you copies of a report by Singh (1964), who described the inability of two young girls found in the Indian jungle to learn to speak because they had spent their early years with a pack of wolves. Slowly, after years, they learned to scream or to moan when trying to focus the attention of the nurses to some problems they recognized, but all this was signal-based communication - not speech. The time window had been closed, and the young women were trapped without language (Chapter 7).

In summary, I argue that genetic factors structure most details of the brain before experience occurs. Environmental input is subsequently only able to modify the innate pattern to some extent and within limits. Genes even impose system-specific time limits for experience to be incorporated. Thus, culture comes too late to shape us to an important extent, and the time frames of cultural influence are under innate control.

Best regards,
Maxim

Melun, September 21, 2003

Dear Maxim,

I must admit that I wasn't aware how prestructured our brain is before external input begins to arrive. But don't you think that some of these studies nevertheless overestimate the impact of innateness? I give you an example.

Humans and a few other animals display a left-right difference in motor control that we call handedness in primates and "pawedness" or "footedness" in the case of cats, dogs, mice, parrots, and so on. The decisive contribution of genetics in handedness has been supported by a large number of studies in families of twins and adopted individuals (Corballis, 1997). Presently, there are several genetic models on the market that show interesting associations between handedness and, for example, the direction of scalp hair-whorl (Klar, 2003). I guess no environmentalist dares to argue that the direction of hair-whorl can be influenced by culture. Nonetheless, it is possible that the final determinant of several aspects of behavior derive from the environment. These arguments come from studies with birds, where the factors controlling the ontogenetic events that resulted in the establishment of cerebral asymmetries of the visual system could be clarified.

Birds such as chickens and pigeons show a left hemispheric superiority in processing detailed features of visual objects. As a result of this cerebral asymmetry, they display a right-eye superiority in pattern discrimination tasks (Güntürkün, 2002). The onset of this lateralization starts before hatching. Avian embryos keep their head turned so the right eye is exposed to light, which is shining through the translucent shell, while the left eye is occluded by the body. Because brooding parents regularly turn their eggs and often leave their nests for short time periods, the embryo's right eye has a high probability of being stimulated by light before hatching. This, indeed, is the trigger for the development of visual lateralization because dark incubation of chicken and pigeon eggs prevents the establishment of visual lateralization in visual discriminations, and merely 2 hours of light exposure with 400 lux within the last days before hatching suffice to establish visual lateralization in dark-incubated chicken eggs (Rogers, 1982). It is even possible to reverse the direction of the asymmetry by occluding the right eye and exposing the left to light (Rogers, 1996).

Now, why do avian embryos turn their head to the right? All vertebrates, including humans, exhibit a left-right (LR) asymmetry in the position of their visceral organs, as in the case of the heart which invariantly loops to the right side. Experiments with chickens have revealed the genetic mechanisms that determine the embryological events leading to this asymmetry (Ramsdell & Yost, 1998). During normal embryonic development, chains of interdependent genetic factors result in a rightward looping of the heart, a counterclockwise looping of the gut, and finally in a slight torsion of the

embryo with the forehead pointing to the right. This last point is just what is needed to induce visual lateralization. Now, look at this - while the right turn of the head is under genetic control, the induction of visual asymmetry is not. If no light shines on the egg, the animal will hatch with a symmetric brain. Thus, everything looks as if it is genetically determined, but when it comes to shaping the asymmetries of the brain, an environmental input is needed that interacts with the asymmetric head position of the embryo to lateralize the brain.

Conditions in humans may be similar. The rightward spinal torsion is also true for the human embryo, which has a preference for sucking on its right thumb, partly due to an embryonic right turn of its head (Hepper, Shahidullah, & White, 1991). Most newborns still have a preference for a right turn of their heads when in a supine position, and this preference seems to correlate with subsequent handedness (Michel & Harkins, 1986). The preference for right turns of the head still prevails in adult humans, making it possible that this constant bias molds cerebral asymmetries of the developing brain in humans as it does in birds (Güntürkün, 2003).

Taken together, important aspects of brain organization can derive from an interaction of nature and nurture, although they look strictly genetically determined at the first glance. I'm pretty sure that more discoveries like that are ahead of us.

I hope I could convince you.

Hakan

Odense, October 3, 2003

Dear Hakan,

Your story with the asymmetric birds is a good one. I must admit that it's a nice example for the intricacies of biological and environmental interactions. However, these kinds of examples can also be found in the opposite. Just think of the last twist on posttraumatic stress disorder (PTSD) and hippocampal volume that you might also have read about in the scientific press.

As you know, animal research has provided evidence that exposure to severe stress can damage the hippocampus and, thus, the integrity of declarative memory. Such studies point to a neurotoxic role for corticosteroids, elevated levels of which probably damage hippocampal neurons (Sapolsky, Uno, Rebert, & Finch, 1990). The same probably holds for humans and might explain why, in the psychiatric condition of PTSD, the hippocampus is significantly smaller (Stein, Koverola, Hanna, Torchia, & McClarty, 1997). PTSD is a constellation of disabling behavioral and emotional symptoms that occur in some individuals who have experienced severe psychological trauma such as combat, sexual abuse, or natural disaster. These results raise the possibility that psychological trauma may induce neurological damage in humans. The logic would be that humans who experienced severe stress would survive conditions where parts of

their hippocampus would be destroyed. Subsequently, they would suffer from memory deficits, including lapses for the events that caused the hippocampal damage. Recently, Gilbertson et al. (2002) turned this whole logic upside down.

In their study, they examined samples of male monozygotic twin pairs in which one twin was a Vietnam combat veteran and his identical co-twin had no combat exposure. In some twin pairs, the combat-exposed brother developed chronic PTSD, whereas in other twin pairs the combat veteran never developed PTSD. Consistent with previous reports, Gilbertson et al. (2002) also found smaller hippocampal volume in trauma-exposed persons diagnosed with PTSD. The key finding, however, was that the identical twins who were not themselves exposed to combat showed hippocampal volumes that were comparable to their combat-exposed brothers. These noncombat twins had significantly smaller hippocampi than those of combat veterans without PTSD and their noncombat-exposed twins. These data indicate that smaller hippocampi in PTSD represent a preexisting, familial vulnerability factor rather than the neurotoxic-induced product of trauma exposure per se. Thus, what used to be seen as an effect of an environmental factor affecting the brain now has to be seen as a predisposition that is associated with a higher risk for developing PTSD under stressful conditions. Isn't that great?

In summary, some conditions look environmentally induced but aren't. You are right that, however, some effects look genetically determined but are in fact induced by external input. So, we are even. But of course our discussion here is not to have the last word but to better understand what aspects of our biology and what aspects of our environment are responsible for creating us in the way we exist. I would go so far as to say that each single psychological entity of a person is, to at least some extent, influenced by his or her genetics. This may sound dogmatic, but dogmata aren't bad if they are correct.

Maxim

Melun, October 14, 2003

Dear Maxim,

No doubt, both genes and culture form us. But your last dogmatic statement implies a way of thinking that is widespread but incomplete. You assume that information always flows from genes through substrate to behavior: genes \rightarrow brain \rightarrow behavior. But the interaction is both ways: genes \longleftrightarrow brain \longleftrightarrow behavior. Perceiving and attending to some environmental stimuli (e.g., a novel smell) is accompanied by neuronal interactions that can induce the activation of immediate-early genes (IEGs; Montag-Sallaz, Welzl, Kuhl, Montag, & Schachner, 1999). IEGs are genes that show a rapid and transient expression immediately after resting cells are stimulated by extracellular signals such as hormones and neurotransmitters. Meanwhile many IEGs have been described and named with cryptic terms such as

jun, c-fos, arg 3.1, ZENK, CREB, and so on. These genes, once activated, can both activate and repress further gene expression that then controls structural changes of brain tissue. The important point is that the environment controls gene expression. Genes are then the dependent variable. The study of Jarvis, Scharff, Grossman, Ramos, and Nottebohm (1998) is a nice illustration of this link. These scientists studied singing zebra finches that were either singing for courtship in front of a female or alone and therefore just for themselves. They could show that ZENK expression in the song system of these birds showed different patterns for singing for a female or singing alone. Thus, although the song was the same, the internal state of the animals was different, and thus this internal state had the power to drive different brain areas to express IEGs.

If internal states are able to drive the differential expression of IEGs, we should expect psychological states to affect hormone levels. Therefore, I now argue for the reversal of the usual causal contingencies. First, you have a specific thought, and then you induce IE expressions, because your thought is, for your brain, equivalent to an (external) stimulus. Finally, your IEGs induce the production of gene products like hormones, for example. Finally, elevated levels of hormones can alter the shape of your body (possibly everything from synapses to hair growth). Recently, some interesting examples for this chain of events were reported. For example, the consistently better performance seen by teams in various sporting contexts when playing at home is referred to as the "home advantage." Neave and Wolfson (2003) showed that salivary testosterone levels in soccer players were significantly higher before a home game than before an away game. Perceived rivalry of the opposing team was important because testosterone levels were higher before playing an "extreme" rival than a "moderate" rival. Similarly, Salvador, Suay, Gonzalez-Bono, and Serrano (2003) studied anticipatory hormonal and psychological responses of judo players mentally preparing for an official competition and found that this increased both testosterone and Cortisol levels. Elevated hormone levels in turn predicted a better outcome in the competition. Thus, psychological conditions affect hormone release that can subsequently improve success in sports. It is important to note that an increase of testosterone does not depend on physical exercise. Gladue, Boechler, and McCaul (1989) asked volunteers to participate in a computer game against another person. The winner was, unknown to the participants, predetermined by the scientists. Nevertheless, testosterone levels were significantly increased in winners. So, the psychological experience of winning against somebody else activates testosterone release.

Similarly, Born, Hansen, Marshall, Molle, and Fehm (1999) showed that your expectation of having to wake up at a certain time in the morning regulates your timely increase in adrenocorticotropin release before the expected time of waking. A sadder story is that of Elzinga, Schmal,

Vermetten, van Dyck, and Bremner (2003), who showed that female PTSD patients that were victims of childhood abuse have drastically increased Cortisol levels when confronted with verbal reminders of their trauma. In principle, these elevated Cortisol levels can damage the hippocampus of these women.

I think the best study of this whole field is one that was published anonymously. I was told about this experiment but couldn't yet get a hold of a copy. I hope the person who told me about this publication got the details straight. The story is so good that it ought to be true. It's a little paper published by an anonymous ethologist who spent years on a remote island, banding birds, observing animals, and so on. Every 2 weeks, a small vessel took him to a larger island where he would look for female company. After awhile, he recognized that his beard was growing faster in the days before his free weekend. Because he had a lot of time and all necessary instruments at hand, he started to weigh the remains of the beard he shaved every morning. Indeed, a few days before his trip to the inhabited island, his beard started to grow much faster. He recognized the possibly relevant link: first, there were his thoughts about his sexual plans for the weekend. Second, these thoughts changed his hormonal levels, possibly via an activation of IEGs. Third, because androgens stimulate hair follicles in the beard, his elevated levels of testosterone caused his beard to grow faster.

I must say this story is one of my favorites, and I will definitely try to track this paper down. So, my conclusion is that our thoughts and our environment can be seen as an independent variable with respect to genes. The interaction of genes and cultures is therefore a symmetric one.

All the best,
Hakan

Odense, October 28, 2003

Dear Hakan,

Your story of the ethologist's beard growing is my wife Irina's favorite story. She talks about it at every party! I really hope that the story is true.

I am in bit of a hurry because the deadline for the book chapter on bio-cultural co-constructivism is approaching. So, my response will be rather short this time. Yes, you are right that the interaction of genes and culture is reciprocal, but don't forget that your genes limit the entire mental machinery with which you deal with the world around you. It's your genome that specifies how your synapses and all molecular mechanisms that are associated with synaptic plasticity work. Synapses are highly complex little machines with hundreds of variations of their receptors, G proteins, and so on, that ultimately define your speed of thought and the efficacy of short- and long-term synaptic change. Thus, your mental speed and the ease with which you memorize new information are defined by your synapses - and so, ultimately, by your genome (Chapter 11).

Although axonal conductance speed doesn't correlate with intelligence (Reed & Jensen, 1991), the latencies and amplitudes of sensory-evoked potentials (Tan, Akgun, Komsuoglu, & Telatar, 1993) and of various event-related potentials (ERPs) do (Robaey, Cansino, Dugas, & Renault, 1995). The relationship is such that elevated IQ scores correlate with higher amplitudes and shorter latencies. Although there are still many open questions, there is, in general, good support for the synaptic speed theory of intelligence. I have to admit that the physiological measures explain only a small part of the IQ variance; however, because they represent averages of neural activity over major portions of the brain, a higher resolution is probably difficult to expect.

A study by Wright et al. (2001) might be interesting for you to read in this respect. I can send you the pdf if your library doesn't have the journal. These authors investigated what proportion of the variance in the amplitude and latency of the P300 (an ERP that is elicited by unpredictable, unlikely, or highly significant stimuli and that provides an electrophysiological index of the attention and working-memory demands of a task) could be attributed to genetic factors. To this end, they analyzed the P300-data in 335 adolescent twin pairs and 48 siblings, and showed that additive genetic factors accounted for most of the variance in P300 amplitude. Approximately one-third of the genetic variation at frontal sites was mediated by a common genetic factor that also influenced the genetic variation at parietal and central sites. Genetic covariance in P300 latency across sites was substantial, with a large part of the variance found at parietal, central, and frontal sites attributed to a common genetic factor. It is very interesting to see to what extent a physiological measure that covaries with behavioral IQ is genetically associated.

My conclusion is simple. We are like fish swimming in a bowl. Within our little world, we learn and change by the things we encounter. We may dream that we define our horizon by our own mental power, unlimited by our heritage, but in fact we swim within the tiny limits of our own genetic bowl. Sounds pessimistic, but if I don't switch back now to my book chapter, I will have much more reason for pessimism, I guess. Is yours ready?

All the best,
Maxim

Melun, November 5, 2003

Dear Maxim,

I think you got me wrong. I didn't mean that genes do not bind our IQ. The nature-nurture story with respect to the intelligence problem is so old, boring, and solved that I wonder why the media still go on debating it. I also follow to some extent the new data on the physiological correlates of IQ and don't have any problems with them. After all, the genetic contribution

to intelligence obviously has to manifest itself in some brain measures. The ERP data and IQ correlations therefore fit nicely (Chapter 13).

No, my point is different. I will give you an example. I am an atheist, whereas Meltem is Muslim. Surely, neither of these conditions is genetically wired. Meltem and I discuss our ways of interpreting life, and we both have our arguments. Our views have changed over time and possibly will go on changing. These changes reflect the mental impact of new encounters, arguments, and experiences. Obviously, we reflect about these arguments in our brains, and obviously, our brains are wired to some extent by genetic information. We also hear and read new arguments about religion with our sensory organs, which have a genetic blueprint laid down in each of our cells. We think about what we hear and read by using synapses that are genetically tuned. Likewise, we remember old arguments by using memory mechanisms that have a genetic background, and so on, but still the *content* of our thinking is culture. Pure culture. Culture without a single grain of gene. This kind of culture defines most of what we do and what we are. We might be limited in the speed and extent of grasping the essence of complex problems through a mixture of nature and nurture. Our brains may be tuned to the sounds of our language by properties defined early in childhood. Thus, we may have a hard time distinguishing some sounds in Thai or other languages (Chapter 7). All these aspects are secondary, however. Of principle importance for our daily life is only the content, the message as such. You are not going to tell me that the content of our culture is naturebound, are you?

Did you finish the chapter before deadline? I usually do not care too much about deadlines.

Hakan

Odense, November 18, 2003

Dear Hakan,

I have bad news for you. I think our culture is also a mixture of nature and nurture. I will start my arguments with a classical one. I will talk about incest.

Incest is forbidden by law or represents at least a social taboo in more or less all societies. It is obvious that incest over several generations reduces genetic variance and increases the likelihood of alleles with negative consequences becoming homozygotic. All facilities producing inbred animals for research fight with sophisticated mating programs against the adverse effects of inbreeding. The prevention of incest thus makes biological sense. The universality of the incest taboo across all human cultures therefore renders a biological origin of incest aversion likely. Consequently, different authors have already argued for an evolutionary origin of the incest taboo (Lévi-Strauss, 1984). But how, you will ask, should the translation from biology to culture work? Yanai and McClearn (1972) were probably

the first to really show that mice reared with their relatives until weaning avoided them as sexual partners, whereas those that were reared in foster families did not. Thus, learning some cues about the mice that are present during early childhood makes them unattractive as sexual partners. Possibly, the situation in humans is similar for brother-sister incest. In northern Taiwan, a now vanished tradition involved the introduction of the bride in her future husband's home as an infant. Bride and groom were then raised as members of the same family. The name of this kind of bride was Sim-Pua (little sister). By all criteria (increase of divorces, lack of children, likelihood of the male living with a mistress or the female having a lover), Sim-Pua marriages turned out to be the least successful in comparison to other forms of marriages that involved two young adults coming together (Wolf, 1995).

A similar condition was reported by Shepher (1983) for the kibbutz in Israel. Here, babies from different families live from birth on in small groups called kvutza that function like families with many children. Kibbutzim have an ideological background; parents who have their children living in a kibbutz share a similar ideology. They would possibly favor their children choosing a spouse from the kibbutz, but this rarely, if ever, happens, at least for the children growing up within a kvutza. Shepher (1983) was able to gather quite convincing data that for children of the opposite gender, living together for their first 6 years in a kvutza seemed to considerably reduce sexual attraction, although nobody would object and thus there were no taboos to overcome. The incest taboo thus possibly works in us similarly to the way it does in other animals. We learn the individual characteristics of other children who grow up with us within a family. Years later, these characteristics make them unattractive as sexual partners. Because humans usually grow up with their brothers and sisters, incest is prevented by this simple mechanism.

If the incest taboo is rooted biologically, it is easy to see why more or less all cultures have made a taboo out of it. Although some authors (discussed in Lévi-Strauss, 1984) ask why you need a law against something that is already prevented by nature, these modern intellectuals ignore how primitive, village-level social constructions work. There, at the fundament of human social cultural evolution, social taboos result not only out of the harmful, but also out of the unusual. Only because of that were minorities such as left handers seen as something sinful in most societies. The only reason for their status as outcasts was their statistical rareness. The rareness of incest is therefore possibly one of the main reasons it became a social taboo. With the advent of script, social taboos were possibly transformed into laws and have survived until today. Presently, we are living in a time when scrutinizing laws according to their internal logic, consistency, and compatibility with liberal thinking may sweep away the judicial basis of some of our more ancient social customs.

Incest is just one aspect of a much larger picture. During the last 100,000 years, biological evolution has slowly been transformed into cultural evolution (Chapter 2). If you look carefully, you will see that most *topoi* of today's culture are fully compatible with their sociobiological origin. I can almost hear you protesting, but I will explain what I mean exactly. I will start with the Ten Commandments. I don't know if they were also incorporated into Islam. As a child I had to learn them, but now, I have to admit, I only remember two of them (you should neither kill your neighbor nor cast an eye at his wife...). Looking them up after all these years from my old books, I was amazed to what extent they were compatible with my thesis.

1. You shall have no other gods before Me.
2. You shall not make yourself a carved image.
3. You shall not take the name of the Lord your God in vain.
4. Remember the Sabbath day, to keep it holy.
5. Honor your father and your mother.
6. You shall not murder.
7. You shall not commit adultery.
8. You shall not steal.
9. You shall not bear false witness against your neighbor.
10. You shall not covet your neighbor's wife.

Although the first four are more related to the social techniques of keeping a faith in power, the last six are beautifully compatible with the sociobiological mechanisms governing interactions within a small group of interrelated primates for whom the human specialty of large-scale social cooperation has evolved (Fehr & Fischbacher, 2003). Yes, I know, many more complex interpretations can be put forward for the Ten Commandments, but clear-cut cases such as incest and more mixed cases such as religious rules all point to a sociobiological carpet on which our culture is standing. Therefore, I truly doubt that the content (yes, my friend, the content; not the synapses that transport it) of our thoughts, discussions, and dreams today is free of our biological past. I even go a step further and argue that most of our songs, plays, and fairy tales are instantly understandable to everybody, from young to old, because they evoke emotional constructions that are innate to *Homo sapiens* (Chapter 10).

Just reading a beginner's book such as "The Selfish Gene" by Richard Dawkins (1989) suffices to understand why in "Sleeping Beauty" a male prince has to undertake so much nonsense to kiss the young maiden. It is also instantly understandable that Cinderella has to be young and beautiful (but otherwise can be poor), whereas the prince simply goes with being the prince, and so captures social power in his wake. Everybody understands the motives of Cinderella's stepmother who tries to knot the ties between her own (genetically related) daughters and the prince. Did

you know that there are more than 3,000 versions of the Cinderella myth? Almost every world culture has one. She's known as "Yeh Shen" in China, "The Burnt Face Girl" to the Mik'maq tribe, "Tattercoats" in England, and "Marouckla" to the Slavs. Reading studies on human mating preferences against the backdrop of evolutionary science (Buss, 2003) makes clear why the (stepmother) Queen ordered Snow White to be killed when the magic mirror said: "O Lady Queen, though fair ye be, Snow White is fairer far to see."

So, to be specific, my point is not that all social constructions and belief systems are one-to-one biologically constructed, but that they (1) are either directly rooted in biological mechanisms that describe more or less the same behavior (incest is an example of that), or (2) have a biological underpinning that delivers the general emotional or social context on which the social construction can blossom (Cinderella and other tales, operas, and movies are examples).

You said that the religious (non)beliefs you and Meltem have didn't have a grain of biology. I doubt it. The details of religions might be pure cultural heritage, but as long as religions reduce anxiety by (seemingly) increasing the predictability of life, as long as they provide fairy tales that strike a sociobiological chord in all of us, and as long as they produce a hierarchy of social power that could once be translated directly into reproductive success (yes, I know Catholicism is a remarkable exception, but mainly in more recent times), religions will have a fabric of social and biological threads that are inextricably intertwined. In this respect, religions follow the same patterns as most other social constructions.

All the best,
Maxim

Melun, November 28, 2003

My dear friend,

About 3 months ago, I ignited our letter exchange on nature and nurture by commenting on a sentence that you said in passing. This morning, I had time to read all our letters again, one by one. I think I could convince you that experience-related factors shape each aspect of our brain, but you have likewise convinced me that our biology has "crept" into the most inner details of my existence. Thus, I have to accept that our little daughter was born with prewired expectations about the physical and social realities of the world. Equally, I know that the experiences she is going to make will shape everything she is, that is, her whole psychological and physical existence.

You said that as scientists it is our duty to see and paint the larger picture. I agree. But we should draw with little brushes on a huge canvas. We should see the grand parts and the tiny details. Presently, I can only see outlines, maybe here and there a few detailed strokes. We discussed many

battlefields: cortical development, intelligence, cerebral asymmetries, gene numbers, imprinting, incest, and even religion. Wherever we looked, we saw nature and nurture to be present. In some areas, the cultural side dominated, whereas in others, the biological side took precedence. But not a single territory of our mind seemed to be outside the scope of the interaction of biology and culture.

Is this really all we can say? Or are new discoveries ahead of us?

All the best,

Hakan

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