Bachelor’s Thesis

Lateralized Head Turning Bias in Humans – Cues to the Development of Human Cerebral Asymmetries

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Introduction

In the last decades, extensive research was devoted to the questions “What are the roots of cerebral lateralization in humans?“, “Why and how did it develop?”. Answers were searched for on all levels of explanation from genetic determination to prenatal influences to socio-cultural pressure. However, most research clustered around the investigation of functional asymmetries in prenatal and early postnatal stages of child development, often attempting to correlate early lateralization, like head turning preference or asymmetries of reflexes, to later hand use preference and handedness. Although individual handedness is not unique to humans – it has been clearly shown in mammals, for example, mice (Collins, 1977) and primates (Annett, 1985; Previc, 1991) – it is still believed that only humans show a population bias in hand preference (though there are observations that challenge this view (Clapham, Leimkuhler, Gray, and Mattila, 1995; Hopkins, 1993; Hopkins, Bennett, Bales, Lee, and Ward, 1993, as cited in Hepper, McCartney, and Shannon, 1998)). The dextral population bias in handedness and the fact that handedness is one of the most prominent expressions of functional asymmetry in human adults assign it a central role in the approaches to explain the emergence of human cerebral lateralization.

This paper will review the fields research and main theories on the development of cerebral lateralization and report a study conducted with adults. The studies goal was to search for a possible prevalence into adulthood of the well documented head turning preference found in newborns and its correlation to handedness. The results are discussed mainly in the context of Previc’s theory of cerebral lateralization (Previc, 1991).

The overview over the literature is structured as follows. I begin with functional lateralizations observed in the human fetus and newborn followed by the factors possibly contributing to the formation of these lateralizations. The main theories on the development of hemispheric lateralization are reviewed, focusing on Previc’s 1991 theory. I conclude with the motivation for my study on adult head preference and handedness.
Lateralization Found in Prenatal and Postnatal Human Development

Prenatal. At an early point in intrauterine development, the position of the internal organs is determined, the heart to the left or right side off the body’s midline constituting a first clear morphological asymmetry\(^1\).

With increasing fetal body size a factor in the fetus’ environment exhibits a lateraizing influence. The uterus, restricting the space for the growing child, guides the fetus in a certain position. Most fetuses lie in a cephalic position (about 97% immediately prior to birth (Previc, 1991)), about two thirds showing a leftward position with the right side facing out during the final trimester of the pregnancy (Taylor, 1976, cited in Previc, 1991). Discussed as being an influence on later handedness, this argument faces counterevidence by one study which found no correlation between the fetal position and handedness at the age of 7-8 years (Vles, Grubben, and Hoogland, 1989).

A different approach regarding fetal position was proposed by Ververs, Vries, van Geijn, and Hopkins (1994), who showed a dextral bias in fetal head position with respect to the fetus’ body. With increasing gestational age the dominance of a head-in-midline position decreased, giving way to a head-right preference from 32 weeks of age onwards. “Towards the end of a fullterm pregnancy, the majority of fetuses had adopted a lateralized head position which in most cases constituted a right-sided preference.” (Ververs et al., 1994, p. 89)

On the level of functional asymmetries, the first motoric lateralization was demonstrated by Hepper, McCartney and Shannon (1998). Human fetuses exhibit single arm movements as early as 9-10 weeks of gestational age, with 75% showing a preference for their right arm. Also, there exists a preference of fetuses to suck on their right thumb (only 8% sucked on their left thumb) from about the 15\(^{th}\) week of gestational age on (Hepper, Shahidulla, and White, 1991). Although the right thumb preference could not be shown to be significantly linked to the fetus’ position in the uterus, it was positively correlated to postnatal head turning preference.

Postnatal. By far the most studies on the development of human functional lateralization have been run with newborns to investigate functional asymmetries present shortly after birth. Lateralization has been revealed regarding head position preference, asymmetrical tonic neck reflex (ATNR), the Moro response, the grasping reflex, the stepping reflex and asymmetry in responsiveness to various stimuli.

\(^1\)The situs inversus (inverse position of the internal organs) is rather unusual in humans, though. Affecting only about 1 of 10,000 people (Galloway, 1990) it is also stated not to be related to hand preference and the functional asymmetry of the brain for speech (see Annett, 1985, and Previc, 1991).
Several studies confirmed the existence of a head turning preference among neonates in a supine position (Turkewitz, Gordon, and Birch, 1965, cited in Tan, Örs, Kürkcüoglu, and Kutlu, 1992; Coryell and Michel, 1978; Rönnqvist, Hopkins, Emmerik, and de Groot, 1998). When newborns are placed in a supine position they, usually, turn their head to one side, about 88% of newborns turning it to the right (Turkewitz and Creighton, 1974, cited in Tan and Tan, 1999). Coryell and Michel (1978) found that supine head turning preference “was an adequate stimulus for eliciting the asymmetric tonic neck reflex” (Coryell and Michel, 1978, p. 250). Their study showed a positive correlation between the side of the head turning preference and the side on which the ATNR\(^2\) was exhibited. Moreover, they reported a positive correlation between head turning preference and the preferred hand used for a visually elicited reaching task in infants 12 weeks postpartum.

An influence of parental handedness on functional lateralizations in newborns was investigated by Cioni and Pellegrinetti (1982) and Liederman and Kinsbourne (1980), the latter describing a significant correlation between parental handedness and infant’s head turning in response to symmetrically placed stimulation shortly after birth. Cioni and Pellegrinetti found a supine head-right preference and a right bias for the leg in a placing response in offsprings of right-handed parents plus right-handed siblings, as opposed to children with at least one parent or sibling left-handed. However, they did not find significant differences for the ATNR, the stepping reflex and response to tactile stimuli.

Konishi, Kuriyama, Mikawa, and Suzuki (1987) compared children who were nursed in a supine position to those nursed in a prone position, finding a more frequent and longer persisting head turning preference to the right in the supine group, also followed by a greater use of the right hand. Head preference in the prone group diminished earlier and hand use was less consistent with head turning preference. To further investigate the impact of head turning on later handedness, Michel and Harkins (1985) conducted a study comparing neonates with head-right preference to head-left turners. They reported that head turning positively correlates with hand regard and hand movement and that in children with consistent head turning preference the side of head turning is a good predictor for the hand that will be used the most for reaching between 3-18 months of age.

Other early asymmetries in newborns are revealed in the responsiveness to stimuli. Asymmetrical responses have been reported to both auditory and visual, as well as tactile stimuli, some as early as 24 hours postpartum (as reviewed in Turkewitz, 1977). In addition, Turkewitz (1977) studied “the effect of prior head position on the head turning response to

\(^2\) ATNR: Head turning leads to an extension of the limbs on the face side and a flexion of the limbs on the skull side of the body, a posture also know as “fencer’s posture”.
somesthetic stimulation of the perioral region (around the mouth)” (p. 253), describing the elimination of the right bias in the response found in children with supine head-right preference by holding the head in a midline position 15 minutes prior to testing. Hence, he concludes that head position influences responsiveness to stimuli in newborns.

Among the different asymmetrical reflexes in neonates, the Moro response has been correlated to supine head turning preference. By itself the Moro response is asymmetrical to the respect that about 82% of neonates show a shorter onset latency for the right arm, 12% for the left arm respectively (Rönnqvist, 1995). A later study exhibited a positive correlation between a faster onset for the right arm in neonates and a supine right turning preference (Rönnqvist et al., 1998). In both studies the Moro response was elicited vestibular and Rönnqvist et al. proposed an asymmetrical spinal reflex under vestibular control to be the underlying mechanism.

Further reflex asymmetries in newborns have been described regarding the palmer grasp reflex and the stepping reflex. Tan, Örs, Kürkcüoglu, and Kutlu (1992) showed a significantly stronger grasp reflex of the right hand compared to the left hand in neonates on the second day postpartum. In another study, Tan and Tan (1999) had newborns observed for the asymmetry in the palmar grasp reflex and compared the frequencies found to the distribution of handedness in adults. They reported an approximately equal number of left-handedness in neonates and adults, and a similar number of both right-handed neonates and consistent adult right-handers. The large number of mixed-handed neonates was explained by being undetermined at birth and ready to be socio-culturally shaped by a right-handed world. Thus, they could account for the approximately 90% right-handedness in adults.

Peters and Petrie (1979) conducted a study on the stepping reflex in offsprings of self-described right-handed parents. They reported a clear preference for the right foot as leading foot (the foot that flexed and moved upward first, after both feet had established contact to the surface simultaneously) assigning the left foot a supporting function.

A study by Previc and Saucedo (1992) conducted on high school students tried to correlate turning behavior on the stepping test with motoric asymmetries. It demonstrated the existence

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3 Moro response: A complex movement pattern consisting of two phases. In the initial phase, the upper arm abducts at the shoulder while the forearm extends at the elbow together with extensions in the fingers. During the secondary phase, the arm adducts at the shoulder and the hands move towards the chest. Movements of the legs are also involved but are reported to be less consistent (adapted from Rönnqvist et al., 1998).

4 Palmar grasp reflex: polysynaptic somatosensory-motor reflex. It is elicited by touching the ulnar part of a baby’s hand. Thumb and fingers will closely lock the touching object. The reflex is inhibited or suppressed at about 2-4 month after birth.

5 Stepping reflex: When a newborn is lowered to a flat surface until the feet establish contact, coordinated stepping movements occur which involve alternate flexion and extension of each leg. If not practiced, the reflex disappears at about six weeks postpartum.

6 Stepping test: measures the angular deviation of blindfolded subjects while stepping in place.
of a turning bias, but found a nearly equal distribution of right and left turners. The researchers reported a positive correlation between turning bias and footedness, a nearly significant correlation between turning bias and eyedness, but no correlation between turning bias and handedness. They discuss the stepping test as showing weak reliability, though.

Summary.

The section reviewed research reporting lateralizations found in humans, both prenatal and postnatal. Among the prenatal asymmetries, fetal position in the uterus and hand use preference were clearly shown. The postnatal asymmetries vary from a prominent head turning preference in neonates, to asymmetrically increased responsiveness to stimuli, to lateralization in reflexes.

Theories About the Development of Cerebral Asymmetry in Human Ontogenesis

After having generally reviewed existing asymmetries in early human development, I will give an overview of possible explanations for their emergence as present in the literature. I will shortly discuss genetic, postnatal, and socio-cultural explanations allowing more space for the theories regarding prenatal factors, as head turning asymmetry might stem from this developmental phase.

Genetic Explanations. Reviewing the literature, it seems as if the amount of theories proposing a genetic determination of hemispheric lateralization decreases as research on the whole topic increases.

Until the mid 1970s, Annett proposed a genetic model that assumed the existence of a one allele gene with right (r) or left (l) expression yielding genotypes of rr, rl and ll respectively. Realizing that her model, together with all known mechanisms of inheritance, stands in contradiction with the frequencies of handedness in humans observed in large samples, she changed her assumptions and put forward her “right shift theory” (Annett, 1985). According to this theory, handedness in non-human mammals and humans follows a normal distribution (being continuous, thereby) with the distribution of human handedness being shifted to the right of the continuum. The normal distribution of handedness in mammals has no need for a genetic determinism, rather it develops as a result of many small differences present at the two sides of the body during embryonic and fetal growth. Annett, thus, attributes the development of handedness in mammals to prenatal factors. She accounts for the right shift in humans by proposing “there may be a gene that makes its possessor more likely to develop right-
handedness but no gene giving the contrary bias” (Annett, 1985, p.258). Moreover, the theory states that the manifestation of speech, an exclusively human feature, in the left hemisphere is probably genetically determined, and that the right shift of the human distribution of handedness is a by-product of the factor inducing speech in the left hemisphere. This theory can be challenged from different perspectives. First, the normal distribution of handedness in mammals is questioned by results found in mice which report that mice are strongly handed with only few individuals showing mixed paw use in one-paw tasks (Collins, 1977). Second, if there were a gene supporting right preference but no factor biasing to the left, than children of consistent left-handers should show normal distribution of handedness which they do not (Annett, 1985). In a concluding remark to genetic determinism of handedness Annett admits: “There are several indications of a genetic influence on handedness, but the nature of this influence is obscure” (Annett, 1985, p.62).

Though Collins (1977) questions the existence of genes determining left or right biases, he, too, suggests the influence of genes on handedness. From experiments on inbread mice he infers the existence of genes which determine only the magnitude of handedness not coding the side of preference.

Also, from a genetic point of view parental handedness should predict functional asymmetry in offsprings. There is contradictory evidence regarding this question. Both Liederman and Kinsbourne (1980), and Cioni and Pellegrinetti (1982) found evidence to the extent that parental handedness predicted head turning preference. Moreover, the preferred leg in a stepping test is predicted by parental handedness (Cioni and Pellegrinetti, 1982). Cioni and Pellegrinetti could not show a correlation between parental handedness and the ATNR in children, although the latter has been reported to be positively correlated to supine head turning preference, in a study with small sample size (Coryell and Michel, 1978). Counterevidence is present in Previc’s theory (1991). After reviewing the literature, he concludes that “parental handedness fails to predict either offspring birth position or early postural asymmetries” (p.300).

There are researchers who suspect genetic factors to be the source of cerebral lateralization in humans, for the reason that postnatal factors can be excluded by the studies revealing functional asymmetries being present shortly after birth (e.g., Hepper, 1998). Usually, they do not take into account the possibility of prenatal factors.

Postnatal factors and socio-cultural pressure. A vast amount of research has shown the presence of functional asymmetries shortly postpartum and even before birth (see review
above). This is clear evidence against a lateralization determining factor not exhibiting its influence before birth. Nevertheless, this should not mean that postnatal and socio-cultural influences does not exist, at all. Especially hand preference is not as clearly right biased in newborns as it is in adults, as most studies reveal. Hence, there is space for postnatal and socio-cultural factors to further shape what is presumably laid out before birth.

Prenatal factors. It has been widely proposed that lateralization might somehow be influenced by genetic factors, however, it mainly develops due to factors accompanying the development of the fetus and newborn. Theories supporting the latter view have, in particular, been put forward by Boklage, Geschwind, and Previc. I will shortly discuss the former two, more detailed the latter one. Also, there have been assumptions that prenatal stress could contribute to the development of lateralization, but this view has been rendered implausible by a study showing no correlation between prenatal stress and handedness (Schwartz, 1988). In his theory, Boklage (1980) takes a cellular developmental perspective on the emergence of asymmetries in humans. He proposes an early cellular mechanism in embryogenesis as critical factor for the emergence of lateralization, but does not fully exclude it from being genetically coded. One of the basic tenets of his theory is that there must be a structural asymmetry underlying any functional asymmetry. He speaks of a function assigning process that determines which tissue should serve which function. Hence, there must be a structural determinant “traceable to the cellular processes responsible for the general differentiation between the left and right side of the body” (Boklage, 1980, p.118). Research on twins and embryogenesis leads him to the assumption that these cellular processes take place in the first 8 days of embryogenesis. As a possible candidate for the first lateralization in this stage he cites research on rats. The first lateralization found in these mammals so far is a gradient consisting of cells with a higher concentration of dark RNA granules clustering on one side and cells with little RNA but a higher concentration of vacuoles accumulating on the other side of the blastocyst. This gradient is suspected to constitute the first expression of the dorsal-ventral axis. One characteristic of the development of the blastocyst in the stage, proposed by Boklage to be the critical one, is that it takes place without measurable RNA-synthesis being present. Thus, the information guiding this process must be already there, possibly in enzymes already synthesized or concentrations of components in the cytoplasm as Boklage speculates. Another assumption made in the theory is that monozygotic twins constitute an anomaly of embryonic symmetrical development because two separate body symmetries must be constructed from

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7 The results of this study should be treated with care, though, as it partly relies on maternal reports to determine pregnancy complications.
cells that would produce a single bilateral body symmetry otherwise. Boklage again speculates that left-handed individuals might be survivors of monozygotic twin pairs, thus, individuals with disturbances in early embryonic development.

Geschwind’s theory of cerebral lateralization (McManus and Bryden, 1991) approaches the problem from a hormonal perspective. The development of hemispheric lateralization is said to be controlled by the testosterone level present during prenatal development. The theory proposes a classification of cerebral lateralization in a standard dominance pattern (SDP) and anomalous dominance (AD). The former describing occurrences of both right-handedness and left-hemispheric dominance for speech as well as right-hemispheric dominance for visuo-spatial processing. Any alteration of this pattern, even weakness in one of the constituents, is regarded as AD. Normal testosterone level ensures the development of a standard dominance pattern, whereas increased testosterone level leads to a delayed growth of the posterior left hemisphere and, hence, to anomalous dominance. Increased testosterone level also accounts for modified immune development and immune disorders, as well as giftedness (e.g., increased mathematical or musical abilities) and many more parameters linked to the above mentioned (see McManus and Bryden, 1991, for a detailed picture). The critical factor for the development of cerebral lateralization is environmentally determined, however, testosterone level is regarded as being partly under genetic control. Referring to Previc (1991), Geschwind’s theory can be challenged at various points. Among others, Previc names the great difference in intrauterine testosterone levels regarding boys and girls which shows no similarity to the comparatively small difference found between male and female handedness frequencies, and the finding that “reduced anatomical asymmetries in the fetal brain typically reflect greater right-hemispheric development rather than reduced left-hemispheric development” (Previc, 1991, p. 319).

Previc’s theory (1991) is one that does not attribute all occurring asymmetries to a single underlying factor, but instead proposes the existence of two independent systems each leading to different aspects of human cerebral lateralization. Nevertheless, he puts forward the existence of a “normal” ratio of 2:1 (right : left) as distribution for every occurring asymmetry, where ‘normal’ means ‘without influences from factors like socio-cultural pressure’. Evidence on the weak (if any) correlation between hemispheric speech dominance and handedness led Previc to suspect the two systems to be differentially responsible for each one of them. Findings regarding the correlations between right ear advantage and speech hemisphere, and handedness and visuo-spatial hemisphere dominance respectively build the basis for the theory. Thus, the independent systems are the one determining ear advantage and hemisphere dominance for
speech and another establishing handedness and hemispheric dominance for visuo-spatial processing.

The former system is traced back to a cranio-facial asymmetry present in human development, which might be due to cerebro-vascular asymmetries possibly present in the first trimester of pregnancy. The enlarged facial region on the left side in about two thirds of newborns is assumed to restrict the motion of the mandible. For the latter one is known to be associated with conductive hearing loss (see Previc, 1991), Previc proposes a disadvantage of the left middle-ear conduction, hence, an advantage of the right ear. Although this advantage is established prior to birth, it is only able to exhibit itself as soon as the ear is placed in an aerial environment, hence postpartum. Shortly after birth neonates show a slight right ear advantage which manifests itself in the well known right ear advantage for higher frequencies (REA)\(^8\) found in adults. The advantage of the right ear for frequencies especially between 1000 to 6000 Hz, again, gives the left hemisphere an advantage in perceiving speech sounds\(^9\), which, according to the theory, supports the production of speech also to settle in the left hemisphere.

Within the second system, Previc attributes motoric asymmetries and the right-hemispheric dominance for visuo-spatial processing to an underlying asymmetry in the vestibular system. In the third trimester of pregnancy, about two thirds of fetuses lie in the left cephalic position (head down, right side facing out), which is said to predict later supine head turning and hand preference. The explanation offered by the theory assumes that maternal walking movements apply different stimulation to the fetus’ left and right vestibular systems, in particular to the utricle\(^10\), because the inertial forces during the shorter acceleration phase (about 100 ms) more effectively act on the ear facing outward (usually the right ear), whereas the inertial forces during the longer lasting deceleration (about 400ms), primarily, stimulate the left ear (see Previc, 1991, for a more detailed description). Now, the time constant of the utricle itself is too fast to be affected by this asymmetry, but that of primary otolithic afferents might be sufficiently long to register the difference. Thus, the more salient force acting on the left ear would produce an advantage of the left vestibular system. This, also, means that the motoric asymmetry stems from neural, rather than structural imbalances.

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8 The right ear shows an advantage for frequencies above 1000 Hz, the left ear favors those below 1000 Hz. If dichotic stimuli both fall in one of the categories the ears exhibit advantages for the relative higher/lower frequencies respectively. The REA and LEA are supposed to appear on a subcortical rather than cortical level (Previc, 1991).

9 Prosodic elements of speech are known to be transmitted by frequencies below 1000 Hz, whereas elements critical for word and speech content perception are carried by frequencies greater than 1000 Hz (Previc, 1991).

10 Utricle: part of the otolithic section of the vestibular system, responsible for detecting linear acceleration.
The left vestibular advantage is supposed to affect different systems. First, it favors the right posterior temporal gyrus by supplying it with more input than the left one receives from the less developed right utricle and afferents. The posterior gyrus again projects to the parietal lobe, thereby, presumably giving the right parietal lobe an advantage in visuo-spatial processing. Second, the left vestibular advantage establishes itself as enhanced vestibulo-spinal reflexes, specifically, the ipsilateral reflexes controlling antigravity muscle extension. Hence, the left side of the body exhibits better control of body and posture support. Previc claims that only this gives the right side/ left hemisphere the possibility to develop control over advanced voluntary movements and skilled motoric performance, leading to right-handedness and right-footedness respectively.

The theory, also, provides an explanation for the “right shift” in human motoric preference. It signals the emergence of the erect posture in humans for a shift in fetal position. Now, the fetus is no longer aligned with the inertial force axis during maternal walking movements which would lead to an equal stimulation of both vestibular organs, but rather resides orthogonal to it resulting in the vestibular asymmetry described above. Since the theory aims to explain motoric lateralizations in humans it, also, has to account for the differences regarding the frequencies of left-handedness found between the sexes. Previc suggests socio-cultural pressure as a possible factor in so far as girls might tend to conform to them more often than do boys. Moreover, he cites that male fetuses move more than female ones in the second trimester of pregnancy and slightly beyond, which could result in a enhanced bilateral stimulation of the vestibular organs and, hence, in weaker handedness. The latter argument is hardly convincing though, because fetal movements are restricted by the uterus, especially in the last trimester of pregnancy when the vestibular asymmetry is said to develop.

The theory also faces critique from other points. To mention just a few, the explanation for the development of the facial asymmetry which is said to lead to the REA lacks a solid basis, especially the anchoring in the first trimester of pregnancy. Also, Previc cannot clarify the emergence of the left ear advantage for lower frequencies as frequently found in adults (Previc, 1991). Another possible argument against the theory is a study by Previc and Saucedo (1992). They failed to demonstrate a correlation between turning behavior on a stepping test (assumed to be vestibularly elicited) and handedness in high school students. The results were interpreted by claiming the test was not reliable for assessing turning bias. One, too, could conclude that vestibular asymmetries and handedness do not have the same underlying mechanism, though.

Searching for possible prenatal explanations for the development of cerebral asymmetries, there have been attempts to trace the development of hemispheric asymmetry back to a spinal
asymmetry. The results of the studies by Peters and Petrie (1997), Hepper et al. (1991), Hepper et al. (1998), Rönnqvist (1995), Rönnqvist et al. (1998), Tan et al. (1992), and Tan and Tan (1999) suggest the existence of an early spinal asymmetry that underlies the later cerebral lateralization.

Summary

In this section, literature regarding the mechanisms of the development of cerebral lateralization in humans was reviewed. Beginning with theories proposing genetic factors, I discussed Annett’s “right-shift” theory and the correlation between parental handedness and asymmetries in children. Postnatal factors and socio-cultural pressure were excluded as direct determinants for cerebral lateralization, due to findings in fetuses cited earlier. Theories specializing on prenatal factors included Boklage’s theory of early cellular mechanisms controlling structural asymmetries, Geschwind’s model of testosterone level as the determinant of hemispheric asymmetries, and Previc’s theory of two independent systems, one responsible for auditory and speech lateralization, the other for an vestibular asymmetry leading to motoric and visuo-spatial lateralizations.

Motivation for my Study

The picture that emerges from the research conducted and the theories proposed so far is that the most basic mechanisms underlying the development of cerebral lateralization, genetic or not, are yet to be determined, however, the asymmetries in human behavior definitely emerge well before birth. It is also obvious that postnatal head turning preference could be an important factor in the establishment of motoric asymmetries, and handedness in particular (see esp. Konishi et al., 1987, as cited above). Handedness in children is not completely established before the age of 6 years, though (Peters and Petrie, 1997). Thus, if head turning preference did not completely disappear but were still present in children and even adults it could possibly influence, or even establish, other motor asymmetries (Onur Güntürkün, personal communication).

Therefore, the research which is the motivation for the reported study is a study on head turning preference in adults conducted by Güntürkün (Onur Güntürkün, personal communication). He addressed the question in a study observing couples while kissing. For a “real” kiss, people have to tilt their head to one side, because of nose and face morphology. The study reports the existence of right and left kissers, with 65.1% of couples leaning their head to
the right and 34.9% to the left respectively. Güntürkün did not access the kissers handedness, though. Also, it is not clear how the interaction of two people with different head preference influences the overall result. Thus, a setting is needed in which adults can be observed while showing spontaneous head turning, possibly as reflexive or partly reflexive behavior. No stimulus should be present that could bias the head turning to one side.

For the experiment reported here, the martial art Ju Jutsu was chosen which is the only martial art practicing the “Sturz vorwärts” (falling forward). This fall is meant for a situation in which a person is heavily pushed from the back or even caused to fall by pulling his or her legs simultaneously backward. For practicing, a person lets theirself fall straight forward while tensing the muscles to keep the body as a straight line. She lands on her forearms with the body being still all tense, the only contact with the ground being the toes and the forearms. During the fall, the person turns the head to one side and keeps it in this position to protect the face in case of a wrong landing. This action is assumed to be by itself free of any external influence that would bias the direction of head turning.

The fall forward is practiced in every Ju Jutsu class. All observed instructions were given as “Turn the head to one side”. To further exclude a bias given by the trainer the examinations were made at different schools. People were observed for the direction of head turning during the fall forward and assessed for handedness afterwards. If there were a head turning preference prevalent into adulthood it should show itself in a non-equal distribution of right and left turning in the trials of a person, and head turning being an influence on other motoric asymmetries should establish itself in a correlation to handedness, thereby exhibiting a bias to one side in the population.
Method

Participants

Five Ju Jutsu clubs accepted the request to conduct the study during their class: Crocodiles e.V. in Osnabrück, PSV Münster in Münster, VfL Bad Iburg Abt. Ju Jutsu e.V. in Bad Iburg, Tokio Hirano Köln e.V. in Köln, and PSV Köln 1922 in Köln. Forty-two people, six women and 36 men, participated in the study, aging 23 to 63 years (mean = 35). Ju Jutsu beginners in the classes were excluded to ensure the participants being comfortable with performing the fall. The participants were no professional sportsmen but attended the martial arts class only in their spare time.

Procedure

In all schools, I participated in the warm up training which, apparently, relaxed the people with me as unknown person with a strange calling. Practicing of different falls followed, before the actual training started. During the latter one, the subjects took a short break to take part in the experiment. The floor of a Ju Jutsu practice room is completely covered with mats. The experiment took place with me sitting at one edge of the mat facing the subject from the front providing me with the best view on the persons head turning. Also, this was meant to exclude a turning bias possibly due to my position to the participant. The other people were doing their exercises at least two meters apart in the back of the person. There were no other people walking by or coming into or leaving the room during the whole procedure. Nevertheless the position of the participant with respect to the door was varied from school to school. No other possibly distracting factors were present.

Each person performed the fall forward in five consecutive trials, and thereafter was assessed for handedness. Head turning for every trial was noted allowing for comments on possible unforeseen influences, like hands not touching the floor simultaneously, but there was no occasion the like.

Handedness was assessed by the Edinburgh handedness inventory which is a subjective measure asking for hand preference in ten items (Oldfield, 1971, see appendix for a copy of the questionnaire).
Results

Head turning preference was sorted into four categories. People who turned their head to the right (left) in at least four of the five trials were regarded as right-turners (left-turners). The criteria of four out of five rather than three out of five was chosen to exclude chance to a conservative extent. Although keeping the head in the middle was a clear violation of the instructions, it occurred with a frequency that justified a separate discussion (15.2% of the trials). Thus, one category reflects people who kept their head in the middle in at least four trials. Participants showing inconsistent head turning with respect to the former definitions were regarded as having no head turning preference. Of the 42 subjects, six turned their head consistently to the right (14.3%), four kept the head in the middle (9.5%), 13 people exhibited no preference (45.2%), and 19 persons were assigned to be left-turners (31%). Hence, it was only slightly above chance that people showed a preference for head turning. Among the women, five were left-turners, one kept her head in the middle, which would suggest the existence of head turning preference in females, were there a bigger sample size. Figure 1 illustrates the frequencies and proportions also with respect to sexes.

![Figure 1. Head turning preference (Häufigkeit = frequency)](image)
Looking only at those 25 persons who showed a left or right head turning preference, one finds a clear bias to the left with 76% left-turners versus 24% right-turners (Figure 2).

![Figure 2. Head turning preference of people who showed a side preference (Häufigkeit = frequency)](image)

The Edinburgh handedness inventory gives a handedness laterality score (hls) for a person’s handedness ranging from -100 (strongest left-hander possible) to 100. Participants scoring above 70 hls were regarded as clear right-handers, the others constituting a left/ambidextrous group. Along these lines, 28 subjects (66.7%) were strong right-handers, whereas 14 people (33.3%) showed left/ambidextrous handedness, among the former being five women, among the latter one. This distribution differs from the distribution of handedness found in larger populations by housing much more consistent right-handers than the 23.7 percent reported for the general population (Tan and Tan, 1999) and hardly any left-handers, especially since only one person scored below zero (compare Oldfield, 1971).

A $\chi^2$-test showed no significant relatedness of handedness and head turning preference ($\chi^2 = 2.633$, df = 3, p>0.05), but five of eight cells had expected frequencies below five. For an appropriate statistical analysis, head turning categories were reduced to right-turners and non-right-turners (subsuming left-turners, middle and no preference) to allow for a Fisher’ exact test which is only applicable for two-times-two-designs but handles low cell frequencies. Again a test on handedness and head turning did not prove to be significant (p>0.05, Fisher’s exact = 0.645, two-tailed), the same test separately conducted for the two sexes and for only those subjects who showed either a right or left head turning preference yielded similar results.
Discussion

The three principal findings of this study were that (a) there was no profound existence of a head turning preference, (b) among those people exhibiting a preference a strong majority showed a leftward bias, and (c) head turning preference did not correlate with handedness.

A conspicuous finding in the data was that in many trials the head was not turned to one side at all. It is conceivable that the observer’s position by sitting in front of the subject distracted the person and yielded a midline position of the head when the subject tried to look at the observer during the task. Also, people who attended judo classes before they started to learn Ju Jutsu tend to keep their head in the middle as it is often taught in judo. Moreover, speaking to the subjects and trainers after the experiment was conducted revealed that more experienced persons were completely aware of which side they turned their head to and that they varied the side intentionally. This, clearly, renders the task insufficient to show a head turning bias inert to the nervous system as voluntary control could inhibit (quasi-) reflexive behavior.

The unusual distribution of handedness among the subjects was probably due to the rather small sample size, at least there is no obvious reason to suspect a difference in the distribution of handedness usually found in the population and the distribution among people practicing Ju Jutsu.

As for the missing relationship between handedness and head turning preference, it can not be excluded that the trainer influences the side of head turning, not by the oral instruction but rather by demonstrating the fall. People might try to copy the procedure as accurately as possible, thereby overwriting any possible inert preference for head turning. Again, this calls for a different design than the one used for this study to assess a possible head turning bias in adults.

The finding that the head turning preference shown by those participants who exhibited a preference was biased to the left rather than to the right side might be counterintuitive at first glance. Putting the fall forward in the context of everyday Ju Jutsu practice, though, draws a different picture. In Ju Jutsu the attacked person always aims to get the aggressor under control. Thus, the fall is only the first reaction to an attack from behind, followed by a movement that places the fighter on one side of his or her body freeing the other side, especially the arm and leg, for further actions. People reported that they usually turn their head in the direction of the side they plan to turn their body to, right after the fall. Thus, the preference could be interpreted not as head turning preference but as a cue for a preference for the side to lean on during later defense actions. A preference of the left side for body support, especially antigravity flexion of
muscles, opposed to the right side for skilled and voluntary movements is consistent with findings reported by Peters and Petry (1979) and Previc (1991). Thus, this study supports the theory that one side of the body serves as support side whereas the opposite side is occupied with voluntary movement.

Seen in the context of the emergence of lateralized behavior in humans, the interpretation of the findings as expression of a preference for the left side for body support rather than as head turning preference seem to corroborate Previc’s argument regarding the vestibular asymmetry which underlies later handedness. The theory claims, though, that the establishment of the support side precedes and, thus, determines the side preference for voluntary movements (Previc, 1991). This view is highly challenged by Hepper et al. who reported clear motoric lateralization in fetuses as early as from the 10th week of gestational age on (Hepper et al., 1991; Hepper et al., 1998). In the maternal uterus, a hand or arm should be able to move without the need for any support from the other side of the body, simply due to the fetus’ posture and the gravity conditions within the uterus. This evidence renders Previc’s claim that the support side is constituted first implausible.

Moreover, Previc suggested that the lateralization of the vestibular system which underlies later motor asymmetries takes place in the last trimester of pregnancy. Again, the findings by Hepper et al. contradict this approach. As Previc accepts supine head turning preference to be a predictor of later hand preference and Hepper et al. demonstrated a clear positive correlation between fetal thumb sucking and supine head turning preference, the factors determining these lateralizations must be suspected to act well before the third trimester of pregnancy. Yet, it could still be feasible that motoric asymmetries stem from a lateralization in the vestibular system.

As an explanation for the development of this vestibular asymmetry, though, the theory proposes an asymmetrical influence of the inertial force on the fetus’ two utricle during maternal walking (see introductory section for more details). This is highly questionable from a physics point of view, since the inertial force during acceleration as well as deceleration should act to the same degree on the utricle, regardless of their position relative to the maternal body. An asymmetry, therefore, would have to be already present in the way each utricle responds to linear acceleration from different directions. There is no reason to suspect such an asymmetry, rather each utricle is assumed to detect acceleration in each possible direction (Goldberg and Hudspeth, 2000, in Kandel, Schwartz, and Jessell, 2000, p. 804). This does not rule out the possibility for stronger utricle reactions to specific directions of acceleration, though. Again, it can not be convincingly argued that a vestibular lateralization does not precede motoric
asymmetries, however, the explanations given by Previc appear to be rather fragile. Nevertheless, the general approach to assign the different asymmetries found in humans to more than one underlying system should receive attention as this could explain the weak correlations between various lateralizations (Previc, 1991).

Moreover, the approach to trace the emergence of cerebral lateralization back to prenatal factors still seems to be the most promising one. As argued earlier, socio-cultural factors have been proven unreasonable by the lateralizations repeatedly found early after birth, without denying a possible influence that could strengthen or even suppress lateralized behavior established by other (earlier) factors. Genetic factors can not be ruled out, but too little is known to consistently place them in a theory about the establishment of hemispheric lateralization.

As for the development of motoric lateralization and especially handedness, the first cues have been found in the lateralized arm movement and thumb sucking in fetuses. Together with the thereby predicted postnatal supine head turning preference and a following enhanced regard of one hand, later handedness could be laid out. In these lines, Turkewitz (1977) suggested that “[d]espite the critical role the infant’s posture plays there is evidence suggesting that the relationship between posture and responsiveness may be reciprocal rather than unidirectional” (p. 255). Supposedly, this principle of bidirectionality holds for every stage of the development of human handedness, simply because the brain is a structure self-organized via a vast amount of feedback projections.

To get an elaborate picture of how cerebral lateralization emerges, more research is needed that clarifies issues like the role of genetic factors, the correlations and causalities between the different functional lateralizations found prior to and after birth, and whether there are more than one underlying system leading to functional asymmetries. Up to now, most studies, especially those involving fetuses or neonates face the same problem of very small sample sizes as this study did leaving it rather impossible to generalize the findings for the population.

In addition, since it has not been able to prove in this study whether there is a head turning bias prevalent into adulthood or not, the question if this would or would not influence other lateralized behavior remains to be addressed in a different experimental design, one that allows to observe head turning behavior in a situation without any bias to one side. Reliable results could allow for conclusions about the influence of a head turning preference on the establishment of lateralization, even with respect to early development of the latter.
References


Hopkins WD. 1993. Posture and reaching in chimpanzees (Pan troglodytes) and orangutans (Pongo pygmaeus). *Journal of Comparative Psychology* 107: 162-8


Appendix

a) Edinburgh Inventory Questionnaire for assessing of handedness (German version)

b) Form used for collection of data in Ju Jutsu classes
EDINBURGH HANDEDNESS INVENTORY

Name (Vp-Nr): ..............................................
Alter: .......................................................... 
Geschlecht: ......................................................


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<td>8</td>
<td>Besen (oberste Hand)</td>
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<td>Streichholz anzünden (Streichholz)</td>
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Erklärung

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe.

Antje Petzold, Osnabrück, 21.10.2002