

# Sex differences in social and mathematical cognition: an endocrine perspective

Jack van Honk <sup>\*</sup>, Henk Aarts <sup>\*</sup>, Robert A. Josephs <sup>\*\*</sup> and Dennis J.L.G. Schutter <sup>\*</sup>

At the upper end of spectrums, males outperform females in mathematical cognition (i.e., processing information relevant for understanding the physical world) and females outperform males in social cognition (i.e., processing information relevant for understanding the social world). To be precise, sex differences in thinking about physical problems are observed in top-tier scientific environments, whereas sex differences in thinking about social problems are observed under more interpersonal, empathetic circumstances. One idea is that these differences are due to biologically based cognitive capacities that would differ between males and females. Here we would like to challenge this view and argue that biologically based motive drives principally underlie disparity in mathematical and social ability between the sexes. These motive drives are produced by the sexually dimorphic neuroendocrine system, and presently we highlight the role of the gonadal hormone testosterone. Testosterone is omnipotent in all sex differences in brain and behaviour, first because this male type hormone by itself and by way of its metabolite, the female type hormone oestradiol, builds both male and female brains. Moreover, testosterone influences our motive drives in such a way that we want to understand the mechanical world and the hormone improves performance under highly challenging conditions. Finally, testosterone conveys no affiliative motives or motives to understand people as its affinity with sociality purely depends on sex, money or status. The largest hormonal difference between the sexes is observed for testosterone, thus the hormone's specific motivational properties may well explain sex differences in mathematical and social cognition. (*Netherlands Journal of Psychology*, 64, 177-183.)

Keywords: mathematical cognition; social cognition; sex differences; stereotypes; testosterone; motivation

\* Department of Psychology, Utrecht University

\*\* Department of Social Psychology, Texas University, USA  
Correspondence to: Jack van Honk, Department of Psychology,  
Utrecht University, Heidelberglaan 2, NL 3584 CS Utrecht,

e-mail: J.vanHonk@uu.nl

Received 15 August 2008; revision accepted 30 September 2008.

Worldwide, the academic faculties of universities in the fields of mathematics and science are overwhelmingly male. It has been suggested that fewer women are employed in mathematics and science faculties because women have less built-in aptitude for mathematical cognition. Males and females would be differentially predisposed, with male children more easily grasping mathematical information about objects and their mechanical relationships, whereas female infants more easily grasp social information about people, their emotions, and personal relationships. Males accordingly have cognitive systems that allow effective reasoning in mathematics (Baron-Cohen, 2003).

In a notable review, Spelke (2005) suggests that these claims are mistaken because infants show few cognitive sex differences, and male advantages in the processing of objects, space, or number are unproven. Spelke observes differences between the performance of males and females on certain cognitive tasks in adulthood, but there is no evidence for sex differences in overall aptitude for mathematical cognition at any point in development. Finally, research in highly talented students reveals some disparities in performance on speeded tests of quantitative reasoning, but abilities for mathematical cognition do not differ between the sexes (Spelke, 2005). Although these observations are compelling, the critical question remains unanswered: why do males outperform females on mathematical cognition at the upper end of the spectrum, in top-level sciences? Alas, Spelke escapes this question by explicitly not considering sex differences in 'human preferences, motives, attitudes, temperament, and decisions' (Spelke, 2005, page 950). In doing so, her account seems to be about ability to perform in the psychological laboratory rather than about true performance in real life or under challenging and threatening conditions. The ecological validity of her theory and arguments is therefore questionable, because motivation and other affect-related processes can underlie many performance domains.

Accordingly, Spelke may have misread Baron-Cohen (2003), who proposes that biological predispositions make males, on average, better in thinking analytically, or systemising (mathematical cognition) whereas females are better in empathising and processing information about social interaction, a process central to the study of social cognition. Baron-Cohen does not talk about cognitive capacities in Spelke's terms but argues that the motive or drive to identify another's mental states underlies superior empathising. In the same manner, excellence in mathematical reasoning is brought about by a biologically built-in motive drive to obtain knowledge about objects and their relationships. Much confusion exists about sex differences in mathematical and social intelligence. This may result from misunderstandings of the workings of endocrine mechanisms and evolutionary, neuro-

biologically and functionally mistaken notions of the interdependencies between motivation and cognitive capacities. These misunderstandings offer a breeding ground on which stereotypical thoughts and misguided scientific reasoning on mathematical and social cognition come to flourish.

In this perspective, we aim to elaborate on these relations by highlighting the role of the gonadal hormone testosterone. The largest hormonal difference between the sexes is observed for testosterone. Thus the hormone's specific motivational properties may help to explain sex differences in performance of mathematical and social cognition. Moreover, existing social stereotypes about sex differences in ability in mathematics and social cognition may persist, as testosterone motivates performance in these two fundamental domains differently under conditions of status-related challenge and threat that results from the stereotypes. Thus, by providing a better understanding of the role of testosterone in sex differences in mathematical and social cognition we hope to open new insights into how such differences emerge and to nail down the existence of the stereotypes we have about them.

### Mathematical cognition

In 2005, Harvard University president Laurence Summers was heavily criticised for suggesting that innate differences in mathematic ability distinguish the sexes at the upper end of the performance spectrum in science. His arguments concerning the innate quality of females' biological disadvantage were unfounded, but reached the status of a media feeding frenzy which can potentially work as a self-fulfilling prophecy for this notorious sex stereotype. Whether or not Summers was politically incorrect, we are still waiting for an explanation for sex differences in performance in mathematical cognition at the upper end of the scientific spectrum. In this paper we argue that much of the variance associated with sex differences in mathematical cognition is mediated by the hormone testosterone, and therefore unlikely to be cognitive-intellectual in nature but rather motivational in origin. Misconceptions regarding the interrelations between motivation and cognitive abilities, together with a misunderstanding of the function of the reproductive axis, prevent scientific progress in the field. Throughout history, diverging testosterone levels have played an essential role in the formation and maintenance of female submission and male dominance (Niculescu & Akiskal, 2001). Although in modern societies the functionality of this sex-type social hierarchy is severely attenuated, the hormone keeps on sending the ancient message in us that produces sex-linked feelings and thoughts of competence and incompetence when dealing

with challenges and threats (Josephs, Newman, Brown, & Beer, 2003).

Take, for example, the following study from our laboratory (Aleman, Bronk, Kessels, Koppeschaar, & van Honk, 2004) on mental rotation, one of the most difficult forms of spatial cognition. Testosterone levels of healthy young women were temporarily elevated to the levels of males by way of a single 0.5 mg administration of testosterone in a placebo-controlled study, which resulted in improved learning performance on mental rotation. Typically, such behavioural effects are attributed to testosterone-induced changes in cognitive or intellectual ability. However, although superior performance in complex forms of cognition unmistakably relates to testosterone (Postma, Meyer, Tuiten, van Honk, & Koppeschaar, 2000), one should distinguish carefully between *ability* and *performance* in light of the neurobiological evidence which suggests that the hormone targets cognition primarily by way of motivation (van Honk et al., 2004).

When faced with the challenge of having to perform an intellectual task, a person's performance has been shown to depend critically on two factors: (1) baseline levels of testosterone, and (2) whether one was in a low or high status role in the domain of the task. Specifically, challenges to one's status have been shown to evoke thoughts and feelings of inferiority or superiority, depending on one's testosterone level. Importantly, as a result of these testosterone- and status-related thoughts and feelings, subsequent intellectual performance either suffered or benefited (Josephs et al., 2003; Josephs, Sellers, Newman, & Mehta, 2006). These data suggest that lower testosterone levels may be viewed as a biological proxy for submissiveness, whereas higher levels may be viewed as a proxy for dominance (Wingfield, Hegner, Dufty, & Ball, 1990).

A recent article by Newman, Sellers and Josephs (2005), published in *Hormones and Behavior*, opened Pandora's box by letting *the mind deceive the brain*. Individuals with high levels of testosterone were psychologically manipulated into an inferior submissive position, and - strikingly - their performance on a test of spatial ability dropped to a level well below that of the low testosterone subjects.

From the same group, a study revealed the devastating power of the sex stereotype itself on intellectual performance (Josephs et al., 2003). In a mixed-sex university population, all of whom were selected for being highly motivated to excel at mathematics, math performance was assessed. Theorising from the notion that testosterone levels influence behaviour only under condition of status challenge or threat (Wingfield et al., 1990), the authors demonstrated that social stereotypes about sex differences in math abilities affected performance on a math task differently for men and women. Specifically, the positive stereotype about male mathematic abilities (i.e., an expectation of success) *improved* performance

among high testosterone males as a result of experiencing a challenge to further enhance the higher status position, whereas negative stereotypes about female mathematical abilities (i.e., an expectation of failure) turned challenge into threat of status for high testosterone females resulting in decreased performance (see Schmader, Johns, & Forbes, 2008, for possible mechanisms by which threat may impair such performances). Under conditions of low baseline levels of testosterone, nothing happened in terms of threat and performance. This indicates that stereotype-hormone interactions can increase sex differences in *scientific performance* associated with biologically based motive drives without the involvement or alteration of cognitive or *intellectual ability*.

A compelling thought that generalises from these data is to argue that high testosterone women, especially those few who find themselves at the highest levels of the academic spectrum, constantly face a battle not only with the Laurence Summers' of the world but also with their own inner voice of doubt and inferiority created by the threat that their own strong desire for high status does not match with a world that sees them as unsuitable for such positions. Comparably, high testosterone males not only feel superior in these high status positions, but also confirm the scientific community's beliefs in the notion of exceptional innate intellectual cognitive qualities associated with the male of the species.

When holding in mind that testosterone has clear reward-sensitivity enhancing and punishment-sensitivity reducing properties (e.g., van Honk et al., 2004), one can see how sex stereotypes are preserved. Superior performance of high testosterone (always male) rodents in spatial environments is typically explained in terms of superior cognitive ability (Jonasson, 2005). However, to get the animal to act in the environment, rewards need to be applied, and high testosterone rodents arguably yearn for rewards. Their superior spatial performance can be explained in terms of motivation (Newman et al., 2005).

A motivational hypothesis will enjoy confirmation when a shift in the motivational properties of the task from reward to punishment results in more punishment-sensitive animals (namely, lower testosterone—almost always female rodents) becoming the better performers (cf. van Honk et al., 2004). If animals with relatively lower testosterone levels learn faster in punishing spatial environments, their superior performance could be explained in terms of motivation (i.e., coping with anxiety and potential threat) with no reference to cognitive or intellectual ability. Importantly, recent data on attention orienting show that in humans punishment and reward-related motivations improve spatial cognition (Engelmann & Pessoa 2007).

In sum, testosterone may mediate sex differences in mathematical cognition at the upper end of the spectrum in part because the hormone motivates one to understand the nonsocial world (Baron-Cohen, 2003), but primarily because under conditions of threat or challenge the hormone motivates the individual to learn under specific reward contingencies. In line with the challenge hypothesis, coping with challenge is rewarding for individuals with high levels of testosterone, but is of little help to performance in social cognition because social cognitive processes generally occur automatically and effortlessly (Dijksterhuis, Chartrand, & Aarts, 2007).

### Social cognition

Outstanding performance in parsing the social world has been argued to importantly underlie the evolutionary success of humans (Kringelbach & Rolls, 2003). However, in modern societies social intelligent abilities are much less appreciated than mathematical abilities. The intelligent quotient (IQ) and not emotional quotient (EQ) is the golden standard and parents even tend to be proud of socially retarded autistic children with some excellent mathematic abilities. The term standardly used for this social deficit is ‘high-functioning’ autism, which is a pretty odd concept for an evolutionary relapse.

This seemingly positive stereotype regarding autism again works out negatively for females because autism is observed primarily in the male population. Crucially, in Baron-Cohen (2003), high levels of foetal testosterone masculinise the brain and predispose the individual for autism. Excellence in parsing one’s social world—in essence, high performance in social cognition—enabled humans to communicate and cooperate and live together in peace in very large groups. Herein, females take the lead because they are better in automatically and effortlessly reading other people’s minds and responding appropriately (Baron-Cohen, 2003). Indeed, sex differences have been observed in emotion recognition, social communication and mind reading. There is increasing interest for these sex differences in social cognition research. Evolutionary arguments have been proposed for this female superiority. One idea is that historically, females migrated to the social group of their mate, whereas males remained in their birth group. Females therefore were forced to form social alliances with non-kin (Geary, 2002).

Baron-Cohen (2003), as mentioned above, proposes that on average, females are better at social cognition *because of their inherent motive* to identify another’s mental states and respond to these with an appropriate emotion. Sociability may be more rewarding for the female brain and hence females may be more motivated to seek and secure social ties (van Honk, in press). This notion is by no means speculative in that the neurobio-

logical mechanism can be tied to oxytocin-opioid interactions in reward centres of the brain. Oxytocin-opioid interactions are superior in females (Curly & Keverne, 2005) and might well be antagonised by testosterone (van Honk, in press). Relative to the male brain, the female brain is arguably motivated for superior social cognition because its hormonal circuitry has an evolved reward-seeking basis in social behaviour.

In short, female-specific motives involve understanding the social world and thus correctly identifying another person’s beliefs and desires and then responding appropriately. Male-specific motives involve understanding the mathematical world, i.e., understanding objects and their mechanical relationships. Thus, in general, males may be more challenged by mathematical issues and women by social/interpersonal issues. Moreover, threatening people’s current status role by offering them social stereotypes may cause those people with high levels of testosterone to become worse in solving the issues. Indeed, as we discussed before, when one’s status is threatened as a result of priming the negative stereotype, women perform worse on a mathematical task, especially when they have high baseline testosterone; men with high baseline testosterone tend to become better when they can confirm the positive stereotype and enhance their status (Josephs et al., 2003).

However, there is some recent evidence showing that men may suffer from negative stereotypes in social skill domains as well (Hall & Mast, 2008; Koenig & Eagly, 2005). In one study (Koenig & Eagly, 2005), men and women had to perform a social sensitivity task assessing the ability to accurately interpret the expressive behaviour of others and to decode others’ nonverbal cues – an aspect of social intelligence or social competence (Archer, Costanzo, & Akert, 2001). Unlike the mathematical cognitive skills, social sensitivity may involve relatively automatic processes (Aarts, Dijksterhuis, & Dik, 2008). Important for the present purpose, male and female participants were primed or not with the stereotype that men do worse than women on this ability. Results showed that the stereotype prime impaired males’ performance, whereas females’ performance was slightly increased by the stereotype prime. When the stereotype prime was absent, men and women performed equally well.

These results suggest that men and women were differently motivated as a result of threat and challenge of their status in the social skill domain, thereby pointing to a potential role of testosterone and oxytocin in social cognition. Although this line of reasoning is tempting, we should be careful here. There is ample evidence showing that stereotype primes can affect performance directly by means of a perception-behaviour link (Aarts et al., 2005; Dijksterhuis et al., 2007). Thinking about being slow or fast, helpful or unhelpful, or good or bad in a social

sensitivity task can cause one to act in accordance with the prime without intention. Accordingly, it may be the case that men and women simply acted on the stereotype without status threat or challenge being involved in the first place.

Keeping focus on testosterone, the hormone of challenge (Archer, 2006) seems to have little affinity with sociability, at least when it does not bring about testosterone's 'true' rewards such as sex, money or status. Research targeting human social cognition is, however, in its infancy and individual differences in social cognition and the unmistakably involved neuroendocrine mechanisms have received little attention.

Nonetheless, human research indicates that the neuroendocrine system establishes individual variation in social cognition (Montagne, van Honk, Frigerio, Burt, Perrett, & de Haan, 2005; Kosfeld et al., 2005; Schultheiss, Wirth, & Stanton, 2005; van Honk et al., 1999, 2004), and is accountable for enhanced empathic, mind-reading and emotion recognition abilities in females (Domes, Heinrichs, & Michel, 2007; Hampson, Anders, & Mullin, 2006; Hermans, Putman, & van Honk, 2006; van Honk & Schutter, 2007). However, supporting the high functioning autism stereotype above, female scientists put forth efforts in attempting to defend the notion that females and males have similar cognitive talents in mathematical cognition (Spelke, 2005). But many talented people come up short because in the end motives are especially critical at the highest levels of performance spectrums where obstacles and challenges require additional effort and resources.

Moreover, the superiority in social cognition suggests that the female brain is evolutionarily further evolved than the male brain. Evidence for this assumption comes from the famous Social Brain Hypothesis from behavioural biology (Dunbar, 1998) which has received very little attention in the psychological and biological sciences. Dunbar's Social Brain Hypothesis holds that increases in social group size underlie increases in the size of the primate neocortex. However, Lindenfors (2005) recently showed that the Social Brain Hypothesis applies to females exclusively, and that the male brain may even show a slight decrease when the social group size increases.

Recent behavioural data indicate that the motives underlying male and female social behaviour differ considerably. Female social behaviour stems from pro-social motivations whereas male social behaviour seems mostly instrumentally driven (e.g., Aarts, Gollwitzer, & Hassin, 2004; van Vugt, de Cremer, & Janssen, 2007). Testosterone's role in sex differences in sociality can be

seen in recent data using testosterone administrations in placebo-controlled designs which show that the hormone increases fairness and social cooperation when this sociality pays off moneywise. If not, sociality fades away (Eisenegger, Heinrichs, & Fehr, 2008; Tromp, van de Vugt, Bos, Terburg, & van Honk, 2008).

## Conclusion

From early development until death testosterone together with its female-type metabolite oestradiol construct the sexually dimorphic brain (Carter, 2007; van Honk, in press). Testosterone is omnipotent in sex differences in brain and behaviour, as the hormone by itself and by way of its metabolite, the female type hormone oestradiol, builds male and female brains. Moreover, testosterone influences our motive drives in such a way that we want to understand the mechanical world, and the hormone especially improves performance under highly challenging conditions. Importantly, testosterone conveys no affiliative motives or motives to understand people as its affinity with sociality is purely instrumental and depends on sex, money or status. Critically, the largest hormonal difference between the sexes is observed for testosterone and adds up to the hormone's specific motivational properties to explain sex differences in mathematical and social cognition. Finally, social stereotypes about sex differences in mathematics and social cognition may also interact differently and in complex ways, and although testosterone may motivate performance primarily in mathematical cognition, in certain social situations involving status-related challenge and threat the hormone might also strive for excellence in social cognition.

In sum, sex differences in mathematical and social cognition depend on differential (social) motive drives that are generated by sexually dimorphic neuroendocrine circuitry wherein the gonadal hormones testosterone and oestradiol play important roles.

## Acknowledgements

Jack van Honk was supported by a High Potential Grant from Utrecht University, Henk Aarts was supported by an NWO VICI grant (452-02-047), and Dennis J.L.G. Schutter was supported by an NWO VIDI grant (452-07-012) from the Netherlands Organisation for Scientific Research (NWO).

## References

- Aarts, H., Chartrand, T. L., Custers, R., Danner, U., Dik, G., Jefferis, V. E., & Cheng C. M. (2005). Social stereotypes and automatic goal pursuit. *Social Cognition*, 23, 465-490.
- Aarts, H., Dijksterhuis, A., & Dik, G. (2008). Goal contagion: Inferring goals from others' actions - and what it leads to. In J. Y. Shah & W. Gardner (Eds.), *Handbook of motivation science* (pp. 265-280). New York: Guilford.
- Aarts, H., Gollwitzer, P. M., & Hassin, R. R. (2004). Goal contagion: Perceiving is for pursuing. *Journal of Personality and Social Psychology*, 87, 23-37.
- Aleman, A., Bronk, E., Kessels, R. P. C., Koppe-schaar, H. P., & van Honk, J. (2004). A single administration of testosterone improves visuospatial ability in young healthy women. *Psychoneuroendocrinology*, 29, 612-617.
- Archer, D., Costanzo, M., & Akert, R. (2001). The Interpersonal Perception Task (IPT): Alternative approaches to problems of theory and design. In J. A. Hall & F. J. Bernieri (Eds.), *Interpersonal sensitivity, theory and measurement* (pp. 161-182). Mahwah, NJ: Erlbaum.
- Archer, J. (2006). Testosterone and human aggression: an evaluation of the challenge hypothesis. *Neuroscience Biobehavioral Reviews*, 30, 319-345.
- Baron-Cohen, S. (2003). *The Essential Difference*. Penguin, Basic Books.
- Carter, C. S. (2007). Sex differences in oxytocin and vasopressin: Implications for autism spectrum disorders? *Behavioural Brain Research*, 176, 170-186.
- Curley, P. J., & Keverne, E. B. (2005). Genes, brains and mammalian bonds. *Trends in Ecology and Evolution*, 10, 561-567.
- Dijksterhuis, A., Chartrand, T. L., & Aarts, H. (2007). Effects of priming and perception on social behavior and goal pursuit. In J. A. Bargh (Ed.), *Social psychology and the unconscious: The automaticity of higher mental processes* (pp. 51-131). New York: Psychology Press.
- Domes, G., Heinrichs, M., Michel, A., Berger, C., & Herpertz, S. C. (2007). Oxytocin Improves "Mind-Reading" in Humans. *Biological Psychiatry*, 61, 731-733.
- Dunbar, R. I. M. (1998). The Social Brain Hypothesis. *Evolutionary Anthropology*, 183, 178-190.
- Eisenegger, C., Heinrichs, M., & Fehr, E. (2008). *Testosterone increases norm compliance*. Presented at the 2008 ISPNE meeting, Dresden, Germany.
- Engelmann, J. B., & Pessoa, L. (2007). Motivation sharpens exogenous spatial attention. *Emotion*, 7, 668-674.
- Geary, D. C. (2002). Sexual selection and sex differences in social cognition. In A. V. McGillicuddy-De Lisi & R. De Lisi (Eds.), *Biology, society, and behavior: The development of sex differences in cognition* (pp. 23-53). Greenwich, CT: Ablex/Greenwood.
- Hall J. A., & Mast, M. S. (2008). Are women always more interpersonally sensitive than men? Impact of goals and content domain. *Psychological Bulletin*, 34, 144-155.
- Hampson, E., van Anders, S. M., & Mullin, L. I. (2006). A female advantage in the recognition of emotional facial expressions: Test of an evolutionary hypothesis. *Evolution and Human Behavior*, 27, 401-416.
- Jonasson, Z. (2005). Meta-analysis of sex differences in rodent models of learning and memory: a review of behavioral and biological data. *Neuroscience Biobehavioral Reviews*, 28, 811-825.
- Josephs, R. A., Newman, M. L., Brown, R. P., & Beer, J. M. (2003). Status, testosterone, and human intellectual performance: Stereotype threat as status concern. *Psychological Science*, 14, 158-163.
- Josephs, R. A., Sellers, J. G., Newman, M. L., & Mehta, P. H. (2006). The Mismatch Effect: When Testosterone and Status Are at Odds. *Journal of Personality and Social Psychology*, 90, 999-1013.
- Hermans, E. J., Putman, P., & van Honk, J. (2006). Testosterone reduces empathic mimicking in healthy young women. *Psychoneuroendocrinology*, 31, 859-866.
- Koenig, A. M., & Eagly, A. H. (2005). Stereotype threat in men on a test of social sensitivity. *Sex Roles*, 52, 489-496.
- Kringelbach, M. L., & Rolls, E. T. (2003). Neural correlates of rapid reversal learning in a simple model of human social interaction. *Neuroimage*, 20, 1371-1383.
- Kosfeld, M., Heinrichs, M., Zak, P. J., Fischbacher, U., & Fehr, E. (2005). Oxytocin increases trust in humans. *Nature*, 435, 673-676.
- Lindenfors, P. (2005). Neocortex evolution in primates: The social brain is for females. *Biology Letters*, 1, 401-410.
- Montagne, B., van Honk, J., Kessels, R. P., Frigerio, E., Burt, M., Perrett, D. I., & de Haan, E. H. F. (2005). Reduced Efficiency in Recognising Fear in Subjects Scoring High on Psychopathic Personality Characteristics. *Personality and Individual Differences*, 6, 136-141.
- Newman, M. L., Sellers, J. G., & Josephs, R. A. (2005). Testosterone, cognition, and social status. *Hormones and Behavior*, 47, 205-211.
- Niculescu, A. B., & Akiskal, H. S. (2001). Sex hormones, Darwinism, and depression. *Archives of General Psychiatry*, 58, 1083-1084.
- Postma, A., Meyer, G., Tuiten, A., van Honk, J., & Koppeschaar, H. P. F. (2000). Effects of testosterone administration on selective aspects of object location memory in healthy young women. *Psychoneuroendocrinology*, 25, 563-575.
- Schmader, T., Johns M., & Forbes, C. (2008). An integrated process model of stereotype threat effects on performance. *Psychological Review*, 115, 336-356.
- Schulkin, J. (2003). *Rethinking Homeostasis*. New York: Bradford Books.
- Schultheiss, O. C., Wirth, M. M., & Stanton, S. J. (2004). Effects of affiliation and power motiva-

- tion arousal on salivary progesterone and testosterone. *Hormones and Behavior*, 46, 592-599.
- Spelke, E. S. (2005). Sex Differences in Intrinsic Aptitude for Mathematics and Science? *American Psychologist*, 60, 950-958.
- Tromp, D., van de Vugt, M., Bos, P. A., Terburg, D., & van Honk, J. (2008). *Testosterone and social cooperation*. Presented at the 2008 ISPNE meeting, Dresden, Germany.
- van Honk, J., Schutter, D. J. L. G., Hermans, E. J., Putman, P., Tuiten, A., & Koppeschaar, H. P. F. (2004). Testosterone shifts the balance between sensitivity for punishment and reward in healthy young women. *Psychoneuroendocrinology*, 29, 937-943.
- van Honk, J. (in press). *Neuroendocrine manipulation of the sexually dimorphic human social brain*. Guilford, New York.
- van Honk, J., Tuiten, A., Verbaten, R., van den Hout, M., Koppeschaar, H. P. F., Thijssen, J. & de Haan, E. H. F. (1999). Correlations among salivary testosterone, mood, and selective attention to threat in humans. *Hormones and Behavior*, 36, 17-24.
- van Honk, J., & Schutter, D. J. L. G. (2007). Testosterone Reduces Conscious Detection of Signals Serving Social Correction: Implications for Antisocial Behavior. *Psychological Science*, 18, 663-667.
- van Vugt, M., de Cremer, D., & Janssen, D. P. (2007). Sex differences in cooperation and competition: the male-warrior hypothesis. *Psychological Science*, 18, 19-23.
- Wingfield, J. C., Hegner, R. E., Dufty A. M. Jr., & Ball, G. F. (1990). The 'Challenge Hypothesis': theoretical implications for patterns of testosterone secretion, mating systems, and breeding strategies. *American Naturalist*, 136, 829-846.