Journal of Human Kinetics volume 21 2009, 5-13
Section I – Kinesiology DOI 10.2478/v10078-09-0001-x

Sensation Seeking and Spatial Ability in Athletes: an Evolutionary Account

by
Ivana Hromatko, Ana Butkovic[1]

The aim of this study was threefold: (a) to examine sex differences in sensation seeking and spatial abilities in a sample of athlete students, (b) to explore whether measures of sensation seeking and spatial ability can be used to distinguish between athletes engaging in sports of different levels of risk, and (c) to explore the relationship between sensation seeking and spatial abilities in a sample of athlete students. A total of 201 students athletes engaged in sports of different levels of risk completed the Spatial relations test, Mental rotation test, and Zuckerman's Sensation Seeking Scale-V. Men scored higher than women in both measures of spatial abilities and on DIS, while women scored higher than men on ES. High-risk group had higher SSS and TAS scores than low- and medium- risk groups, and low-risk group had lower DIS scores than medium- and high-risk group, but there were no differences in spatial ability among athletes engaged in sports of different levels of risk. Spatial ability correlated with sensation seeking measures in men only. The results are discussed in terms of possible common biological background of these two sex-dimorphic traits.

Key words: sensation seeking; spatial abilities; sex differences; sports; evolutionary account

The notion that our hunting-gathering evolutionary history shaped the behaviour of modern humans became widely accepted among social scientists (e.g. Tooby & Cosmides, 1992). Evolutionary psychologists study the design of various evolved psychological features, and the ability of those features to perform specific tasks relevant to survival and reproduction. For example, it has been shown that risky physical activity (such as hunting large game) signals fitness, and consequently, enhances men's reproductive chances (Gomà-i-Freixanet, 2004). Even in contemporary modern societies, in which risk taking may take other forms, physical fitness, displayed through participating in physically risky sports has been shown to increase one's mate value and sexual access (Faurie, Pontier, & Raymond, 2004). Furthermore, main indicators of developmental stability and masculinization appear to be behavioural (Simpson, Gangestad, Christensen, & Leck, 1999). This might provide an answer to the question why should one engage in such, potentially costly behaviour. At another level of analysis (the proximate one), Zuckerman (1994) argued that there were consistent individual differences in optimal levels of stimulation, and proposed a concept of sensation seeking. He defined this trait as a tendency to seek novel, varied, complex and intense sensations and experiences and the willingness to take risks for the sake of such experience. Sensation seeking has been explored in relation to number of various risk-taking behaviours like sexual behaviour, alcohol and drug use, driving habits, gambling and sports.

Roaming through large territories in order to acquire food or mate was an important form of ex-

[1] - *Department of Psychology, Faculty of Humanities and Social Sciences, Zagreb University*

Authors submited their contribution of the article to the editorial board.
Accepted for pinting in Journal of Human Kinetics vol. 21/2009 on May 2009.

ploratory behaviour that took place for a large period of time during human evolution, a behaviour which is also intricately related with risk taking. It is also an activity which would be virtually impossible to perform without an evolved three-dimensional spatial perception. Psychometrically, spatial ability is defined as the ability to judge the relations of objects in space, to judge shapes and sizes, to mentally manipulate objects, or to mentally turn them over (Hurt & Brous, 1986). Linn and Petersen (1985) classified tests that measure different forms of spatial ability into three distinct categories: spatial perception (the ability to determine spatial relations despite distracting information), spatial visualization (the ability to manipulate complex spatial information when several stages are needed to produce the correct solution) and mental rotation (the ability to rotate, in imagination, quickly and accurately two- or three-dimensional figures).

Both sensation seeking and spatial ability are sexually dimorphic characteristics (see Zuckerman, Eysenck & Eysenck, 1978; Ridgeway & Russell, 1980; Ball, Farnill, & Wangeman, 1984; Butkovic & Bratko, 2003 for sensation seeking and Maccoby & Jacklin, 1974; Voyer, Voyer, & Bryden, 1995; Karadi, Szabo, Szepesi, Kallai, & Kovacs, 1999; Kimura, 2000 for spatial ability). It has been consistently found in different samples that men score higher than women on Thrill and Adventure Seeking and Disinhibition subscales (Zuckerman, Eysenck & Eysenck, 1978; Ridgeway & Russell, 1980; Ball, Farnill & Wangeman, 1984; Butkovic & Bratko, 2003). The largest sex differences for spatial ability have been found in mental rotation, while differences in spatial visualization are of smaller magnitude and less consistent (Kimura, 2000; Linn & Petersen, 1985). Along with possible socio-cultural explanations for sex differences in spatial abilities, a strong case for the role of prenatal levels of sex hormones has been built (e.g. Williams & Meck, 1991; Collaer & Hines, 1995; Falter, Arroyo, & Davis, 2006). Men typically have greater prenatal exposure to testosterone, which ultimately leads to different cerebral organization of men and women (Geschwind & Galaburda, 1985). Several markers of both prenatal and adult testosterone levels have successfully been linked to cognitive performance, especially spatial cognition (e.g. Sanders, Bereczkei, Csatho, & Manning, 2005). Similarly, testosterone has been proposed as physiological correlate of sensation seeking (Resnick, Gottesman, & McGue, 1993; Zuckerman, 1994; Aluja & Garcia, 2005). Athletes are an interesting population in this sense, due to their increased levels of androgens, compared to general population (Fellmann, 1992).

Another reason for exploring these two features in athletes is that both the spatial ability and sensation seeking might be considered integral components of some sports – the former being especially important in sports which require precise visuomotor coordination (e.g. throwing ball in specified direction), and the latter being pronounced in sports with heightened risk levels. Furthermore, being an athlete represents a certain life style, and in that sense, athletes can be regarded as a special sample of the population. Consequently, it can be expected for athletes to differ from general non-athlete population in different behavioural outcomes. For example, it has been shown that sensation seeking can be used to differentiate between athletes and non-athletes, with athletes scoring higher on sensation seeking (Schroth, 1995), and between athletes participating in sports of variable risk, with athletes participating in high-risk sports scoring higher than athletes participating in low-risk sports (Gomà-i-Freixanet, 1991; Chirivella & Martinez, 1994; Wagner & Houlihan, 1994; Schroth, 1995; Slanger & Rudestam, 1997; Jack & Ronan, 1998; Zarevski, Marusic, Zolotic, Bunjevac, & Vukosav, 1998). As for differences in spatial ability between athletes and general population, there is no clear pattern of results. It has been shown that athletes performed better than non-athletes in mental rotation task (Ozel, Larue, & Molinaro, 2002), and that more successful football players had higher scores on mental rotation task than less successful ones (Manning & Taylor, 2001), but it has also been shown that, although sport participation at high level of competition is associated with high spatial ability in women, this was not the case for men, who scored lower on the spatial ability test than the control group (Lord & Leonard, 1997).

Sex differences in sensation seeking have also been found among athletes, with male athletes having higher scores than female athletes (Schroth, 1995; Chirivella & Martinez, 1994). Lord and Leonard (1997) have reported no sex differences in spatial ability among athletes, while Lord and Garrison (1998) reported higher scores in female compared to male basketball players. It has been suggested that sex differences in spatial ability might not be as pronounced among athletes, due to improvement in spatial scores of female athletes, which have greater spatial experience, gained through enhanced athletic training and frequent spatial exposure (Lord & Leonard, 1997).

Given the reported inconsistencies in the results of previously reported studies, the aim of this study was threefold: (a) to examine sex differences in sensation seeking and spatial abilities in a sample of athlete students, (b) to test the hypothesis that sensation seeking and spatial abilities measures can be used to distinguish between athletes engaging in sports of different levels of risk, and (c) to explore the relationship between sensation seeking and spatial abilities in a sample of athlete students.

Methods

Participants and procedure

The participants were 201 students (150 men and 51 women) from the Faculty of Kinesiology. Their age ranged between 19 and 27 years (*M* = 20.81, *SD* =1.28). They were tested on two separate occasions: on first occasion they completed the *Spatial relations test* and *Mental rotation test* and on the second *Zuckerman's Sensation Seeking Scale-V* and sport participation questionnaire. Complete data was available for 117 male and 48 female students, and for 33 male and 3 female students only data from second occasion was available.

Measures

Sensation seeking scale. The Croatian translation of Form V of the Sensation Seeking Scale (SSS; Zuckerman et al., 1978) was used for measuring sensation seeking. Form V is a 40-item forced-choice questionnaire and it measures four factors: Thrill and Adventure Seeking (TAS), Experience Seeking (ES), Disinhibition (DIS), and Boredom Susceptibility (BS). Also a total sensation seeking score can be obtained. The Croatian translation has been used previously and internal consistencies were .87 for the total scale and between .50 and .83 for four subscales (Butkovic & Bratko, 2003).

Space relations test. The test measures the ability to visualize a three-dimensional object from a two-dimensional pattern, i.e. participants have to indicate what an unfolded shape would look like when folded (Bennett, Seashore, & Wesman, 1947). Each item consists of one pattern, followed by five three-dimensional figures. Subjects have to choose all figures that can be made from the pattern. Test consists of 40 items, and participants had 10 minutes to complete it. According to Linn and Petersen (1985) this test measures the ability of spatial visualization.

Mental rotation test. A version of Vandenberg & Kuse (1978) mental rotation test was used. Each item consisted of a pair of two-dimensional drawings representing three-dimensional objects. The second object could either be a rotation of the first figure, or its mirror image. The participant had to mentally rotate the object in his/her mind, and to decide whether it was the same or the mirror image. The test consisted of 30 items, 15 of which comprised the same and 15 mirror images. Participants had 3 minutes to complete as many of the items as possible. According to Linn and Petersen (1985) this test measures the ability of mental rotation.

Sport engagement. After completing the *Sensation seeking scale* each participant was asked to complete a general questionnaire which included information about their sex, age, weight and height. After that they were asked to state a sport they are mostly engaged in, and to circle the group of sports they prefer to engage in. Three groups of sports were available based on the level of risk: low-, medium- or high-risk. According to Zuckerman (1983), low-risk sports included running, athletics and gymnastics, medium-risk football, basketball and handball, while high-risk group included parachuting, scuba diving, skiing and mountain climbing. Participants also provided information regarding the use of anabolic steroids, other doping agents and dieta ry supplements, etc.

Results

Based on a marked group of sports the participants were divided into three groups: those preferring to engage in low-risk sports, those preferring to engage in medium-risk sports and those preferring to engage in high-risk sports. Within men 18% were in a high-risk group, 73% in a medium-risk group and 9% in a low-risk group, while within women 33% were in a high-risk group, 45% in a medium-risk group and 22% in a low-risk group. Means and standard deviations for *Sensation Seeking Scale* (total score and four subscale scores), *Spatial relations test* and *Mental rotation test* are presented in Table 1 separately for men and women as well as for the total sample and three groups of sport engagement.

© Editorial Committee of Journal of Human Kinetics

Table 1

Means and standard deviations for Sensation Seeking Scale (total score and four subscale scores) and for Spatial relations test and Vandenberg Mental Rotation test

Measure		SSS		TAS		ES		DIS		BS		MRT		SRT	
Sample		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Males	High risk	23.67	5.46	8.67	1.54	5.04	2.08	6.33	1.96	3.63	2.13	18.47	7.48	38.41	13.01
	Medium risk	22.35	5.46	7.48	2.18	4.93	1.97	6.7	2.11	3.25	1.96	15.76	7.34	35.99	13.79
	Low risk	22.54	5.08	8.38	1.33	5.38	1.76	5.62	2.69	3.15	2.04	15.3	7.68	32.8	11.81
	Total	22.67	5.46	7.79	2.07	5.01	1.97	6.55	2.15	3.33	2.0	16.21	7.41	36.2	13.49
Females	High risk	26.19	4.02	8.31	1.49	7.63	1.67	6.56	1.21	3.69	1.62	8.31	5.86	27.94	14.69
	Medium risk	21.91	4.17	7.5	1.44	6.45	2.04	5.23	2.02	2.73	1.86	13.41	8.55	25.64	15.1
	Low risk	20.18	3.66	7.0	2.72	6.27	1.56	4.36	1.96	2.55	1.64	8.67	4.82	29.22	14.21
	Total	22.76	4.59	7.71	1.84	6.73	1.89	5.37	2.0	2.96	1.79	10.73	7.34	27.35	14.5

Two separate MANOVAs with sex and group of sport engagement as between-subjects sources of variance were conducted: one with SSS scores as dependent variables and the other with *Space relations test* and *Mental rotation test* scores as dependent variables. The results are shown in Tables 2 and 3, respectively.

When SSS scores were entered into analysis as dependent variables, results revealed sex differences in ES (women scoring higher than men) and DIS (men scoring higher than women) and differences for sport engagement, but no interaction between sex and sport engagement. Post-hoc Tukey tests for Sensation Seeking Scale revealed that only high-risk group differed from low- and medium- risk groups in total score and TAS, while only low-risk group differed from the other two on DIS scale.

Table 2

Results of MANOVA with sex and group of sport engagement as between-subjects sources of variance and Sensation Seeking Scale scores as dependent variables

Source of variance	Dependent Variable	*df*	*F*
Sex	SSS	1/192	0.01
	TAS		2.36
	ES		20.71**
	DIS		4.56*
	BS		0.95
Sport engagement	SSS	2/192	5.03**
	TAS		3.41*
	ES		1.44
	DIS		3.77*
	BS		1.93
Sex x sport engagement	SSS	2/192	1.91
	TAS		1.15
	ES		1.65
	DIS		2.30
	BS		0.35

**$p<.01$; *$p<.05$.

Note. SSS = Sensation Seeking Scale total score; TAS = Thrill and Adventure Seeking; ES = Experience Seeking; DIS = Disinhibition; BS = Boredom Susceptibility.

When *Space relations* and *Mental rotation* scores were entered into analysis as dependent variables, results revealed sex differences for both tests with men scoring higher than women, no differences for sport engagement, and an interaction effect between sex and sport engagement for mental rotation scores (Figure 1). As can be seen from Figure 1, although there were significant sex differences for mental ro-

Table 3

Results of MANOVA with sex and group of sport engagement as between-subjects sources of variance and Space relations test and Mental rotation test scores as dependent variable

Source of variance	Dependent Variable	*df*	*F*
Sex	MRT	1/155	17.37**
	SRT		7.91**
Sport engagement	MRT	2/155	1.03
	SRT		0.34
Sex x sport engagement	MRT	2/155	3.26*
	SRT		0.48

**$p<.01$; *$p<.05$.

Note. SRT = Spatial relations test; MRT = Mental Rotation test

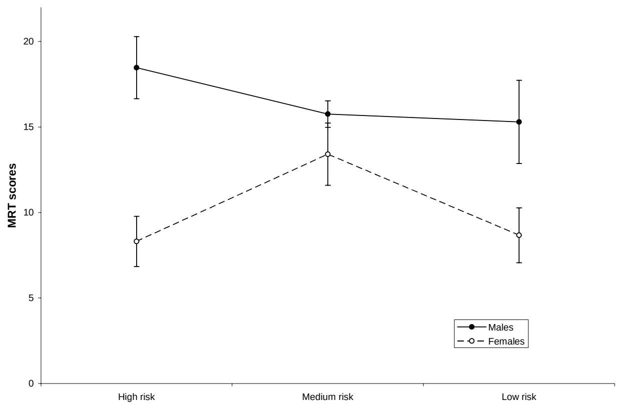

Figure 1
Scores on *Mental rotation test* for male and female athletes who engage in sports of different levels of risk

tation scores among athletes engaged in low and high risk sports, there were no sex differences between men and women engaged in medium-risk sports.

Finally, to test the hypothesis that sensation seeking and spatial ability might co-vary due to their presumed shared background in masculinization processes of androgens, we calculated correlations between sensation seeking scores and spatial abilities scores, separately for men and women. None of the correlations in the female sample was significant. However, in the male sample Mental rotation (but not Spatial relations) scores correlated significantly and positively with several sensation seeking scales: TAS (r= .22, p<.05), BS (r= .23, p<.05) and total score (r=.18, p<.05).

Discussion

This study explores the relationship of sensation seeking and spatial abilities with engagement in sports of different levels of risk. To our knowledge this is the first study that measured both sensation seeking and spatial abilities on a sample of athlete students engaging in sports of different levels of risk. Multivariate analyses of variance were used, with sex and engagement in sports of different risk levels as independent variables, and sensation seeking and spatial abilities as dependent variables. Sex differences in both sensation seeking and spatial abilities were found. Men scored higher than women in both measures of spatial abilities and on DIS, while women scored higher than men on ES. The result for DIS is in line with previous research (Zuckerman et al., 1978; Ridgeway & Russell, 1980; Schroth, 1995; Jack & Ronan, 1998; Butkovic & Bratko, 2003), while ES finding contributes to mixed results obtained in different studies for this subscale. Some studies found no sex differences (Zuckerman et al., 1978; Ridgeway & Russell, 1980; Schroth, 1995; Jack & Ronan, 1998), some found that men scored higher than women (Ball et al., 1984), while Chirivella and Martinez (1994) whose sample was the most similar to ours, consisting of male and female athletes divided in three groups depending on the level of risk, found that women scored higher than men on ES. Also there were no sex differences in TAS which could be expected based on previous research. However, Butkovic and Bratko (2003) obtained the same finding for ES and TAS in their younger Croatian subsample.

Sex differences in spatial abilities were found in both *Spatial relation test* (a measure of spatial visualization) and *Mental rotation test*, with males scoring higher. This suggests that the pattern of sex differences found in general population also exists among athletes. The only exception seems to be the subgroup of athletes engaged in medium level risk sports (Figure 1), where the sex difference in mental rotation scores disappeared, which resulted in an interaction between sport engagement and sex, indicating that sex differences exist only in athletes engaged in high and low risk sports. This could probably be explained by the fact that 45% of women in this group plays handball, a sport that typically requires high visual and motor coordination.

Differences for engagement in sports of different risk levels were found only in sensation seeking. High-risk group had higher SSS and TAS scores than low- and medium- risk groups, while low-risk group had lower DIS scores than medium- and high-risk group. These results are similar to those from previous studies which found differences in sensation seeking scores within groups of athletes participating in sports of different levels of risk (Gomà-i-Freixanet, 1991; Chirivella & Martinez, 1994; Wagner & Houlihan, 1994; Schroth, 1995; Slanger & Rudestam, 1997; Jack & Ronan, 1998; Zarevski et al., 1998). Our results are therefore consistent with the notion that sensation seeking needs of both men and women engaging in sports with higher levels of risk are higher than those engaging in sports with lower levels of risk. As Gomà-i-Freixanet (2004) concludes in the review of research on sensation seeking and participation in physical risk sports, total score and DIS subscale seem characteristic of athletes at any level

© Editorial Committee of Journal of Human Kinetics

of risk as compared to control groups, or high-risk sports as compared to low-risk sports. Also, high-risk takers as compared to medium or low-risk takers are sensation seekers that like the thrill and adventure as indicated by their higher scores on TAS subscale.

As for presumed shared biological background of sensation seeking and spatial ability, our finding that spatial ability, as measured with *Mental rotation test* correlates moderately, but significantly with sensation seeking measures only for men is in accordance with conclusions drawn in another type of studies, showing that prenatal testosterone predicts spatial ability in men, but not women (Sanders et al., 2005). Another line of research, which is also in accordance with this notion, comes from studies of spatial abilities in athletes, where it was shown that, although blood levels of androgen may be associated with spatial ability test scores in men, androgen level does not seem to have a relevant effect on females (Lord & Leonard, 1997). The latter study used current androgen levels as a correlate of spatial ability, i.e. they investigated activation effects of testosterone. Several authors found conflicting results using similar measures: there are reports of both positive (Christiansen, 1993; Janowsky, Oviatt, & Orwoll, 1994; Silverman, Kastuk, Choi, & Philips, 1999) and negative (Shute, Pellegrino, Hubert, & Reynolds, 1983; Gouchie & Kimura, 1991; Kimura & Hampson, 1994) relationships between testosterone levels and scores achieved in the spatial ability tests. Results of recent studies suggest that major effects of testosterone on spatial cognition are the ones that take place prenatally, through their masculinising effects on organization of nervous system (Sanders, Sjodin, & Chastelaine, 2002; Kempel, Gohlke, Klempau, Zinsberger, & Henning, 2005; Falter et al., 2006). The effect of prenatal testosterone on sensation seeking scores has also been investigated using opposite-sex co-twins and second-to-fourth digit ratio. Resnick, Gottesman, and McGue (1993) found that opposite-sex female twins had higher scores than same-sex female twins on DIS and ES subscale, while Cohen-Bendahan, Buitelaar, van Goozen, Orlebeke and Cohen-Kettenis (2005) found that same-sex female twins scored higher than opposite-sex female twins on ES subscale. Austin, Manning, McInroy and Mathews (2002) studied the relationship between 2D:4D ratios and sensation seeking in a sample of 165 students and found significant negative correlations between digit ratio and total sensation-seeking score and also TAS and DIS subscales for females only. Fink, Neave, Laughton and Manning (2006) studied the relationship between 2D:4D ratios and sensation seeking in a sample of 278 German and UK University students. They found significant negative correlations between right- and left-hand 2D:4D ratios and BS subscale and total score for males only, while correlations with other three subscales were also negative but did not reach significance. Although, as can be seen, findings about the effect of prenatal testosterone on sensation seeking scores are mixed, there are indications that sensation seeking scores are to some extent influenced by prenatal testosterone levels. Thus, positive correlations of prenatal testosterone level with both mental rotation and sensation seeking would account for moderate, but positive association between the two measures found in our study. Of course, none of these traits is influenced solely by organizational effects of prenatal testosterone, which is why a stronger connection is not to be expected. We found no correlation between *Spatial relations test* and sensation seeking. According to Linn and Petersen categorization (1985) this is a spatial visualization test, measuring the ability to manipulate complex spatial information when several stages are needed to produce the correct solution. Unlike the *Mental Rotations Test*, which yields the largest sex differences of all spatial tests, tests of spatial visualization usually show small sex differences, or none at all (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995). Research on influence of sex hormones on cognitive abilities showed that activation effects of sex hormones can only be seen in sex-biased tests and not in those which do not show male or female advantage (see Kimura, 2000 for a review). Thus, if sensation seeking and spatial ability indeed share a common testosterone-related biological background, one could expect a relation only between sensation seeking and those facets of spatial ability which are under the influence of testosterone.

Finally, we should state some obvious limitations of this study. The largest one has to do with the characteristics of our sample. Participants for this study were chosen based on their engagement in sports. However, we had quite a limited number of female athletes participating in this study compared to the number of male athletes. Also, the distribution of athletes into groups of different levels of risk, especially for males was uneven with 73% falling into medium-risk group because of their preference for football, extremely popular in Croatia. Therefore it would be interesting to repeat this study on a larger sample with more females participating and with more athletes in each group for three different levels of risk as well as on samples from other countries. Furthermore, it would be necessary to collect precise measures of free testosterone in blood of both men and women, and control for this variable as well. However, methodological problems notwithstanding, it seems to us that the notion of androgens as common biological background in development of spatial abilities and sensation seeking remains a valuable account, as it provides testable hypotheses.

References

Aluja A., Garcia L.F. Sensation seeking, sexual curiosity and testosterone in inmates. Neuropsychobiology, 2005. 51:28-33.

Austin E.J., Manning J.T., McInroy K., Mathews, E. A preliminary investigation of the associations between personality, cognitive ability and digit ratio. Pers Indiv Differ, 2002. 33:1115-1124.

Ball I.L., Farnill D., Wangeman J.F. Sex and age differences in sensation seeking: some national comparisons. Brit J Psychol, 1984. 75: 257-265.

Bennett G. K., Seashore H. G., Wesman, A.G. Differential Aptitude Tests. New York: The Psychological Corporation, 1947.

Butkovic A., Bratko D. Generation and sex differences in sensation seeking: Results of the family study. Percept Motor Skill, 2003. 97: 965-970.

Chirivella E.C., Martinez L.M. The sensation of risk and motivational tendencies in sports: An empirical study. Pers Indiv Differ, 1994.16: 777-786.

Christiansen, K. Sex hormone-related variations of cognitive performance in Kung San hunter-gatherers of Namibia. Neuropsychobiology, 1993. 27: 97-107.

Cohen-Bendahan C.C.C., Buitelaar J.K., van Goozen S.H.M., Orlebeke J.F., Cohen-Kettenis P.T. Is there an effect of prenatal testosterone on aggression and other behavioral traits? A study comparing same-sex and opposite-sex twin girls. Horm Behav, 2005. 47: 230-237.

Collaer M. L., Hines M. Human behavioral sex differences: A role for gonadal hormones during early development? Psychol Bull, 1995. 118: 55-107.

Falter C. M, Arroyo M., Davis G. J. Testosterone: Activation or organization of spatial cognition? Biol Psychol, 2006. 73: 132-140.

Faurie C., Pontier D., Raymond M. Student athletes claim to have more sexual partners than other students. Evol Hum Behav, 2004. 25: 1-8.

Fellmann, N. Hormonal and plasma volume alterations following endurance exercise. Sports Med, 1992. 13: 37-49.

Fink B., Neave N., Laughton K., Manning J.T. Second to fourth digit ratio and sensation seeking. Pers Indiv Differ, 2006. 41: 1253-1262.

Geschwind N., Galaburda, A. Cerebral lateralization: Biological mechanisms, associations, and pathology. I. A hypothesis and a program for research. Arch Neurol, 1985. 42: 428–459.

Gomà-i-Freixanet M. Personality profile of subjects engaged in high physical risk sports. Pers Indiv Differ, 1991. 12: 1087-1093.

Gomà-i-Freixanet M. Sensation seeking and participation in physical risk sports. In: R.M. Stelmack (Ed.), On the psychobiology of personality: Essays in honor of Marvin Zuckerman (pp. 185-199). Elsevier Science/Pergamon Press, 2004.

Gouchie C., Kimura D. The relationship between testosterone levels and cognitive ability patterns. Psychoneuroendocrino, 1991. 16: 323-334.

© Editorial Committee of Journal of Human Kinetics

Hurt R. E., Brous C. W. Spatial visualization: Athletic skills and sex differences. Percept Motor Skill, 1986. 63: 163-168.

Jack S.J., Ronan K.R. Sensation seeking among high- and low-risk sports participants. Pers Indiv Differ, 1998. 25: 1063-1083.

Janowsky J.S, Oviatt S.K., Orwoll E.S. Testosterone influences spatial cognition in older men. Behav Neurosci, 1994. 108: 325-332.

Karadi K., Szabo I., Szepesi T., Kallai J., Kovacs B. Sex differences on the hand mental rotation task for 9-yr-old children and young adults. Percept Motor Skill, 1999. 89: 969-872.

Kempel P., Gohlke B., Klempau J., Zinsberger P., Reuter M., Hennig J. Second-to-fourth digit length, testosterone and spatial ability. Intelligence, 2005. 33: 215–230.

Kimura, D. Sex and cognition. Cambridge, MA: The MIT Press, 2000.

Kimura D., Hampson, E. Cognitive pattern in men and women is influenced by fluctuations in sex hormones. Curr Dir Psychol Sci, 1994. 3: 57-61.

Linn M.C., Petersen A. C. Emergence and characterization of sex differences in spatial ability: a meta-analysis. Child Dev, 1985. 56: 1479-1498.

Lord T.R., Garrison J. Comparing spatial abilities of collegiate athletes in different sports. Percept Motor Skill, 1998. 86: 1016-1018.

Lord T., Leonard B. Comparing scores on spatial-perception tests for intercollegiate athletes and nonathletes. Percept Motor Skill, 1997. 84: 299-306.

Macoby E.E., Jacklin C. N. The psychology of sex differences. Stanford, CA: Stanford University Press, 1974.

Manning J.T., Taylor R.P. 2nd to 4th digit ratio and male ability in sport: implications for sexual selection in humans. Evol Hum Behav, 2001. 22: 61-69.

Ozel S., Larue J., Molinaro C. Relation between sport activity and mental rotation: Comparison of three groups of subjects. Percept Motor Skill, 2002. 95: 1141-1154.

Resnick S.M, Gottesman I.I, McGue M. Sensation seeking in opposite-sex twins: An effect of prenatal hormones? Behav Genet, 1993. 23: 323-329.

Ridgeway D., Russell J.A. Reliability and validity of the Sensation Seeking Scale: psychometric problems in Form V. J Consult Clin Psych, 1980. 48: 662-664.

Sanders G., Sjodin M., de Chastelaine M. On the elusive nature of sex differences in cognition: hormonal influences contributing to within-sex variation. Arch Sex Behav, 2002. 31: 145-152.

Sanders G., Bereczkei T., Csatho A., Manning J. The ratio of 2nd to 4th finger predicts spatial ability in men but not women. Cortex, 2005. 41: 789-795.

Schroth M.L. A comparison of sensation seeking among different groups of athletes and nonathletes. Pers Indiv Differ, 1995. 18: 219-222.

Shute V.J, Pellegrino J.W., Hubert L., Reynolds R.W. The relationship between androgen levels and human spatial abilities. Bull Psychonom Soc, 1983. 21: 465-468.

Silverman I., Kastuk D., Choi J., Philips K. Testosterone levels and spatial ability in men. Psychoneuroendocrino, 1999. 24: 813-822.

Simpson J.A., Gangestad S.W., Christensen P.N., Leck K. Fluctuating asymmetry, sociosexuality, and intrasexual competitive tactics. J Pers Soc Psychol, 1999. 76: 159-172.

Slanger E., Rudestam K.E. Motivation and Disinhibition in High Risk Sports: Sensation Seeking and Self-Efficacy. J Res Pers, 1997. 31: 355–374.

Tooby J., Cosmides L.C. The adapted mind: Evolutionary psychology and the generation of culture. New York: Oxford University Press, 1992.

Vandenberg S.G., Kuse A.R. Mental rotations, a group test of three-dimensional spatial visualization. Percept Motor Skill, 1978. 47: 599–604.

Voyer D., Voyer S., Bryden M.P. Magnitude of sex differences in spatial abilities: a meta-analysis and consideration of critical variables. Psychol Bull, 1995. 117: 250-270.

Wagner A.M., Houlihan D.D. Sensation seeking and trait anxiety in hang-glider pilots and golfers. Pers Indiv Differ, 1994.16: 975-977.

Williams C.L., Meck W.H. The organizational effects of gonadal steroids on sexually dimorphic spatial ability. Psychoneuroendocrino, 1991. 16: 155-176.

Zarevski P., Marusic I., Zolotic S., Bunjevac T., Vukosav Z. Contribution of Arnett's inventory of sensation seeking and Zuckerman's sensation seeking scale to the differentiation of athletes engaged in high and low risk sports. Pers Indiv Differ, 1998. 25: 763-768.

Zuckerman M. Sensation seeking and sports. Pers Indiv Differ, 1983. 4: 285-293.

Zuckerman M. Behavioral expressions and biosocial bases of sensation seeking. New York: Cambridge University Press, 1994.

Zuckerman M., Eysenck S.B.G., Eysenck H.J. Sensation seeking in England and America: cross-cultural, age and sex comparisons. J Consult Clin Psych, 1978. 46: 139-149.

Corresponding author

Ivana Hromatko
Department of Psychology,
Faculty of Humanities and Social Sciences,
Luciceva 3, 10000 Zagreb, Croatia
Telephone: 00385-1-6120193;
Fax: 00385-1-6120037
e-*mail*: ivana.hromatko@ffzg.hr

© Editorial Committee of Journal of Human Kinetics