Mathematical Duel Plus participants' functioning in multinational team competition

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Gender, gender identity, cognitive abilities and mathematical performance

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University of Silesia in Katowice , 2015

Project number 2014-1-AT01-KA201-000908

Title of the project Mathematical Duel Plus 2015-17

A REPORT

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Introduction

Mathematical reasoning ability is a powerful predictor of science achievement in educational settings (Gustin & Corazza, 1994), and one of the most important skills for the high achievements in the area of science, technology, engineering and mathematics academic disciplines (STEM) (Halpern et al., 2007). Widespread concerns about underrepresentation of women among STEM students and professionals (Ceci, Williams, & Barnett, 2009) motivated the researchers and educational institutions to carry out analyses devoted to establish the causes of this underrepresentation, and take appropriate action to fill this gap. A long history of research in the area of gender differences yielded gender similarity hypothesis (Hyde, 2005), that posits the differences between males and females excluding sexuality, aggression and some motor skills (i.e. throw velocity and throw distance) are rather small magnitude, and – according to Hyde's (2005) convention – they can be referred as „trivial". On the other hand, Steele's (1997) well-established stereotype threat effect, in concordance with a social role theory (Eagly, 1987) and vast number of studies about gender stereotype content (Deaux & Lewis, 1984; Mandal, Gawor, & Buczny, 2012), corresponds with the Nash's (1979) gender role mediation hypothesis, states that women and men seek a congruence between their interest and roles. When stereotypically male = math (or science; Nosek et al., 2002; 2009), women may therefore present more negative attitude toward science and mathematics, or even manifest anxiety in tests of gender-typed abilities (see Else-Quest, Hyde, & Linn, 2010), which discourage them to seek a career in STEM disciplines (Eccles, 1994). Additionally, internalization of social gender roles in self-schema (i.e. gender identity; Bem, 1981) may also function as the inhibitor or accelerator of the achievement motivation in STEM.

The Mathematical Duel plus programme, which gathers adolescents from different European countries (Austria, Czech Republic, and Poland) who manifest an interest in mathematics, provides a promising opportunity to examine a predictors of mathematical achievements, and gender differences in so-called gender-sensitive cognitive abilities. The current project was devoted to examine a basic prediction about a mean levels of cognitive abilities and relations between gender, gender identity variables (masculinity and femininity), and stereotype threat elicitation for both cognitive abilities (visuospatial abilities, verbal fluency, and attention) and performance in a mathematical competition that accompanies the Polish edition of the Mathematical Duel plus programme.

In a present description the results of two phases of observation and examination during a programme meeting in Poland, in March 2015, were presented. In first part, there is described an integration activities prepared to examine a patterns of youth communal tendencies in multinational groups. The participants of the March meeting were assigned to several teams and invited to play a plot-based game that create a possibility to both implement the knowledge about cipher techniques (presented in a lecture that took place before the integration game), and to cooperate with colleagues from different countries. According to observational study, the conclusions about the social tendencies of the programme's participants as well as effectiveness of integrative activities were drawn. In the second part of the report, we presented a study that was conducted among participants during the March meeting. In this study the role of gender, nationality, gender identity and stereotype threat were examined for the level of abilities in gender-sensitive areas (visuospatial ability, verbal fluency), and rather gender-neutral ability of attention. This phase unable us to make a simple verification of the most significant hypothesis concerning gender gap in cognitive abilities: gender similarity hypothesis (Hyde, 2005), gender role mediation hypothesis (Nash, 1979), greater male variability hypothesis (Hyde & Mertz, 2009), and compare the results of a selected sample of programme's participants with the results of large meta-analytical studies. The report starts with the theoretical background section, in which the basic concepts in the area of gender differences in cognitive abilities, and mathematical performance predictors are briefly discussed, setting a framework to interpretation especially of the empirical phase of the project.

Gender differences in cognitive abilities: A gender gap in mathematical abilities

Maccoby & Jackline (1974) in one of the first prominent review of studies of gender differences concluded that significant difference between men and women appears in verbal ability, visual-spatial ability, mathematical ability and aggression. After over 30 years of careful testing, Hyde (2005) showed that 78% of gender differences effect sizes[1] is close-to-zero or small magnitude, therefore one may postulate rather gender similarity hypothesis than gender differences hypothesis. As the scope of interest of the present report is the cognitive abilities it should be state that the analyses carried out on the population level found no evidence of gender differences in general intelligence[2], yet some significant differences were found in specific abilities (Halpern and Lamey, 2000; Neisser et al., 1996). Halpern and colleagues (2005) stated that males and females have equal cognitive ability, but their profile of specific abilities is somehow different. Male advantage were found in complex mathematical abilities and spatial abilities (Reilly & Neumann, 2013), while female advantage were demonstrated for reading abilities (Reilly, 2012). Halpern (1997) concluded that females, on average, score higher on tasks that require rapid access to and use

1 The effect size measure used in the reffered meta-analysis is Cohen's d. The computation formula of this effect is as follows: $d = (M_{males} – M_{females})/s_w$, where M_{males} is the mean score for males, $M_{females}$ is the mean score for females, and s_w is the within-groups standard deviation. The Cohen's *d* represents the distance between score for males and females in standard deviation units. Positive values of d represent better performance of boys comparing to girls, while negative means the opposite. Effects lower than 0.20 was refered as small, 0.50 as moderate, and 0.80 as large.

2 Lynn and Erwing (2004) found small gender differences in scores in Progressive matrices in favor of males (d = 0.16 for adolescents between 15 and 19 years old, and d = 0.30 for adults).

of phonological and semantic information in long-term memory, production and comprehension of complex prose, fine motor skills, and perceptual speed. Males, on average, score higher on tasks that require transformations in visual-spatial working memory, motor skills involved in aiming, spatiotemporal responding, and fluid reasoning, especially in abstract mathematical and scientific domains. Males, however, are also over-represented in the low-ability and of several distributions, including mental retardation, attention disorders, dyslexia, stuttering, and delayed speech. The summary of results of varied meta-analytical studies were presented in Table 1.

Table 1. Meta-analytic effect sizes for gender differences in selected cognitive abilities

Meta-analysis	Abilities	Effect sizes (Cohen's d)
Linn & Peterson (1985)	Spatial perception	0.44
	Mental rotation	0.73
	Spatial visualization	0.13
Feingold (1988)	DAT spelling	-0.45
	DAT language	-0.40
	DAT verbal resoning	-0.02
	DAT abstract reasoning	-0.04
	DAT numerical ability	-0.10
	DAT perceptual speed	-0.34
	DAT mechanical reasoning	0.76
	DAT space relations	0.15
Voyer, Voyer, & Bryden (1995)	Spatial perception	0.44
	Mental rotation	0.56
	Spatial visualization	0.19
Hedges & Nowell (1995)	Reading comprehension	-0.09
	Vocabulary	0.06
	Mathematics	0.16
	Perceptual speed	-0.28
	Science	0.32
	Statial ability	0.19

Hyde and Linn (1988) showed that gender differences in verbal ability are rather small magnitude. A meta-analysis of Hedges and Nowell (1995) confirms this results, demonstrating also greater variability of scores in cognitive abilities within boys, and the prevalence of boys in the group of the highest ability levels (in upper 10% the proportion of boys to girl was from 1.5 to 2.34

for mathematics). More recent meta-analyses reported also only small gender differences in cognitive abilities (see Hyde, 2005), with the exception of visuospatial abilities and some aspects of verbal abilities.

Visuospatial abilities

Visual-spatial ability consist of some more specified abilities, like spatial perception, mental rotation, spatial visualization (complex analytic multistep processing of spatial information, i.e. imagine a result of folding a piece of paper in several directions), spatiotemporal ability (ability to reason about dynamic visual displays), generation and maintenance of spatial image (Halpern & LeMay, 2000). Voyer, Voyer, and Bryden (1995) reported that effect sizes for gender differences in mental rotation task are significant and exceed d = 0.30 (in some other analysis they reach a level of 0.90 – Master & Sanders, 1993). Mental rotation is one of the most widely researched areas of cognitive gender differences (Halpern and Lamay 2000), due in part to the fact comparisons of men and women in mental rotation show the largest effect sizes of all spatial tasks (Voyer et al. 1995).

Verbal abilities

Some verbal tasks showed moderate or substantial mean differences favoring females. Females report better memory abilities (Stumpf & Jackson, 1994), spelling (Stanley, Benbow, Brody, Dauber, & Lupkowski, 1992), reading comprehension (Hedges & Newell, 1995), synonim generation and verbal fluency (e.g. naming words that start with i given letter) (Gordon & Lee, 1986; Hines, 1990). Females also showed better performance in communicational skills, e.g. in affiliative speech (Leaper & Smith, 2004), smiling behavior (LeFrance et al., 2003), or facial expression processing (McClure, 2000). However, the gender differences in vocabulary or verbal reasoning are close to zero (Feingold, 1988; Hyde & Linn, 1988).

Mathematical abilities

The analysis of gender differences in mathematical abilities is subjected to specific public context, which on one side enables a difference testing in large studies (TIMMS, PISA), and on the other side, generates some institutional activities focused on the specific shift in the state of gender differences in mathematics (e.g. No Child Left Alone). One line of analysis is oriented to the measurement of the gender gap in mathematical abilities, its dynamics in a function of time and cultural-economic development, and searching for cultural level predictors of this gap. The second line is connected with the problem of greater male variability, that underline a distortion in proportion of male and female in the highest-ability populations. A summary of recent meta-analyses was presented in Table 2.

Table 2. Gender differences in mathematical abilities in selected meta-analysis.

Meta-analysis	Ability	Effect size (Cohen's d)
Hyde, Fennema, & Lamon (1990)	Mathematics computation	-0.14
	Mathematic concepts	-0.03
	Mathematics problem solving	0.08
Hyde et al. (2008)	NEAP mathematical score	0.007
Else-Quest, Hyde, & Linn (2010)	TIMMS[a] Math	-0.01
	TIMMS[a] Algebra	-0.11
	TIMMS[a] Data	0.00
	TIMMS[a] Geometry	0.01
	TIMMS[a] Measurement	0.07
	TIMMS[a] Number	0.01
	PISA[a] Math	0.11
	PISA[a] Quantity	0.06
	PISA[a] Space/Shape	0.15
	PISA[a] Change/Relationships	0.09
	PISA[a] Uncertainty	0.12
Reilly (2012)	PISA[b] Mathematic literacy	0.22 (USA) 0.13 (OECD)

Note. [a] – TIMMS (Trends in International Mathematics and Science Study)/PISA 2003; [b] – PISA (Programme for International Student Assessment) 2009; OECD – Organisation for Economic Co-operation and Development.

Benbow and Stanley (1980, 1983) showed a stable yet small gender differences in mathematical abilities of 12 to 14-years-old. Hyde, Fennema, & Lamon (1990) in their influential meta-analysis for U.S. population showed a negligible gender gap in math performance ($d = -0.05$), but also demonstrated that males outperformed females in complex problem solving ($d = 0.29$). The males advantage in problem solving became lower in more recent analysis (Hyde et al., 2008). Hedge and Nowell (1995) estimate the gender differences in mathematics at d from 0.03 to 0.26 across the different data sets, while in study by Hyde and colleagues (2008) the effect size was close-to-zero, $d = 0.0065$. Else-Quest, Hyde and Linn (2010) demonstrated that gender differences in mathematical abilities are rather small magnitude (mean $d < 0.13$), but there is also a substantial cross-national variability of gender gap (d ranged from -0.42 to 0.40). They interpreted their results in light of the gender stratification hypothesis, and showed that some indices of gender equity (gender equity in school enrollment, women's share of research jobs, and women's parliamentary representation) are powerful predictors of national-level size of gender gap. Else-Quest, Hyde and Linn (2010), using datasets from TIMSS and PISA cross-national studies showed that gender differences in mathematical performance are trivial ($d < 0.10$) in TIMMS, or small in magnitude (d between 0.06 and 0.15) in PISA, what corroborates the gender similarity hypothesis (Hyde, 2005). Larger differences were found for indices of self-efficiency or attitude toward mathematics (in both studies, d between 0.10 and 0.33, whereas female showed higher level of anxiety, d = -0.28). Additionally, using Hyde's (2005) nomenclature, main part of the effect sizes (over 40%) were negligible (d < 0.10), yet there was a significant cross-national variance in gender gap concerning mathematical abilities. Reilly (2012) demonstrated that the gender differences in mathematical literacy was small but non-trivial (in US population the Cohen's *d* was 0.22; in PISA attendants countries *d* was 0.13), and that the difference in significant prevalence of boys and girls was seen mainly at the highest ability level (two boys per girl), while at the lowest ability level the difference was slight. Additionally, measures of gender equity tend to correlate with the size of gender gap in mathematical abilities, so that in countries with higher level of relative status of women, the educational measure of women in research the gender gap in mathematical abilities was smaller (the analysis for OECD countries). The Reilly's (2012) meta-analysis also revealed acompensatory effect of power distance for gender gap. In countries with higher acceptance for inequality (high power distance; Hofstede, 2001) the gender difference was smaller. For countries that participate in the study the gender gap in mathematical abilities was significant yet small, and in favour of boys in Austria, d = 0.22, and trivial in Czech Republic, d = 0.05, and Poland, d = 0.04 (see Table 3).

Table 3. Effects size for gender differences in mathematical abilities and gender equity coefficients in Austria, Czech Republic, and Poland.

	Austria	Czech Republic	Poland
Mathematical	0.08	0.16	0.06
Quantity	0.04	0.06	0.02
Space	0.17	0.25	0.12
Change	0.05	0.13	0.08
Uncertainty	0.08	0.18	0.03
Extrinsic motivation	0.58	0.26	0.05
Intrinsic motivation	0.40	0.26	0.11
Math Anxiety	-0.36	-0.26	-0.03
Mathematics self-concept	0.44	0.36	0.18
Mathematics self-efficancy	0.46	0.42	0.17
SIGE	0.312	0.288	0.683
GGI	0.706	0.672	0.676
WSRP	0.21	0.28	0.39

Note. Positive values of d represent higher scores for males than females, whereas negative values represent higher scores for females; SIGE (Standardized Index of Gender Equality) - includes relative female-to-male access to education, life expectancy, economic activity rate; women's share in higher labor market occupations; women's share in parliamentary seats; weights economic domain heavily; GGI (Gender Gap Index) – is composed of four subindices based on economic participation and opportunity, educational attainment, political empowerment, and health/survival; WSPR (Women's share of research positions) – % of research positions (according to International Labour Organization, 1990) held by women; cited after: Else-Quest, Hyde, & Linn (2010).

Even small gender differences in mathematical abilities in conjecture with other factors, could result in a large disproportions in career paths of adolescents. Benbow and colleagues (2000) showed that among adolescents that demonstrated highest level of mathematical abilities at age of 12 to 14-years-old, twenty years later more males than females secured a degrees in inorganic sciences and engineering, while females tend to choose a medical and biological arts. There was also difference in preferences for career or more balanced life, where males tend to focus on the career, while female were more balanced in their priorities regarding career, family, and friends.

The gender differences in mathematics are especially visible among high scorers, among those a proportion of men to women in this tail of the distribution curve was from 2:1 to even 13: 1 (for the scores higher than 700 in SAT-M) (Benbow & Stanley, 1980; 1983). One of the important explanation of this effect in male greater variability hypothesis (Hyde & Mertz, 2009), which posits that due to greater dispersion of male's results their representation in both lowest and highest range of result is higher than female's. In intellectually gifted samples there is also noted a disproportion between females and males in the number of achieved degrees in math, science (2:1 in favor of males), engineering and physical science doctorates (4:1; Lubinski & Benbow, 1992). Hyde and Mertz (2009) confirmed that males dominated females among those scoring above the 95^{th} and 99^{th} percentile of mathematical abilities. Machin and Pekkarinen (2008) showed that in 34 of 40 countries participating in PISA in 2003, as well as in 33 of 50 countries participating in TIMMS, the variability ratio (variance for male/variance of females) was greater than 1.00. However, Penner (2008) showed that greater male variability is not universal, what can exclude the possibility of biological explanation of these effects, and turn the interpretation into the sociocultural arguments.

The existence of gender differences in mathematical abilities stems from both biological and sociocultural factors (Ceci et al., 2009; Hirnstein, Andrews, & Hausmann, 2014). One of the important contributor is a gender identity (Halpern & LeMay, 2000; Reilly & Neumann, 2013), that reflects the individual variation in the degree to which boys and girls develop and acquiry stereotypical masculine and feminine personality traits, behaviors and interests (Bem, 1974). Spelke (2005) argued that in the case of complex mathematical tasks men and women undertake different strategies of reasoning, i.e. men tend to form an image of one object and mentally rotate it while women tend to focus on the comparison of object's features. Males also estimate their general intelligence, mathematical intelligence, and spatial abilities more favourable than women (Syzmanowicz & Furnham, 2011), what can help them maintain the high achievement motivation in a mathematics (Wigfield & Eccles, 2000).

Sociocultural background of gender gap: A stereotype threat effect and role of the gender identity

Ceci, Williams and Barnett (2009) concluded that sociocultural forces are more powerful predictors of women's decisions according to an area of specialization than biological causes. Eccles and colleagues (Eccles, 1994; Wiegfield & Eccles, 2000) postulated that both sociocultural gender stereotypes and their internalized forms (as referred to some self-construals, like gender identity) predict achievement motivation also in the area of mathematical performance and interests. Below, we briefly describe some prominent approaches in explaining the gender gap in mathematical abilities. We start with the gender stereotype content, which establish the connection between math/science and being a male. Next, we reported the gender stratification hypothesis, expectancy-value theory of achievement motivation, stereotype threat effect and gender identity role in mathematical performance.

Explicit and implicit gender stereotypes

Gender stereotypes includes both explicit and implicit beliefs about female inferiority in mathematics (Bhana, 2005; Nosek et al., 2002), and could possess an important impact on girls and women by impairing their math performance (Spencer, Steele, & Quinn, 1999), and learning process (Appel, Kronberger, & Aronson, 2011). Oswald (2008) showed the interplay between stereotype activation and gender identification in the area of linking and sense of ability of gender-typed occupations. Additionally, Tomasetto, Alparone and Cadinu (2011) demonstrated that parents' stereotype endorsement also shape the way children are affected by stereotype-driven effect, like stereotype threat.

Explicit and implicit gender stereotypes independently impact both self-construal connected with mathematics but also math performance. Explicit stereotypes tend to be correlated with self-perception of math ability (Passolunghi, Ferreira, & Tomasetto, 2014). Implicit “male = science/math” associations at a national level, as measured by IAT, showed a pattern of positive correlation with national gender difference in science performance, and in mathematics performance of 8-graders (in TIMMS) (Nosek et al., 2009). The explicit stereotype was also positively correlated with the gender gap in science and math performance (TIMMS 2003). Taken simultaneously, only implicit attitude math = male was a significant predictor of the gender gap in science and mathematical performance (accounting for 19% and 24%, whereas explicit stereotype for 2% and 1%).

Gender stratification hypothesis

Baker and Jones (1993) showed that gender differences in mathematics were smaller in more gender-equal nations than in less-equal nations and proposed the gender stratification hypothesis that posits a positive relation between gender equality and gender gap in mathematics. Generally, the gender stratification hypothesis proposes that where there is more societal stratification based on gender, and thus more inequality of opportunity, girls will report less positive attitudes and more negative affect and will perform worse on mathematics achievement tests than their male peers. Social gender stratification results in girls' poorer math achievements and more negative attitudes toward mathematics (Baker and Jones, 1993).

In large scale cross-national analysis the gender stratification hypothesis gains some verification. Guiso and colleagues (2008) demonstrated that the empowerment of the role of women in society is correlated with gender gap in mathematical skills, even when the economic development is controlled. Else-Quest, Hyde, and Linn (2010) provided also limited evidence in favor of the gender stratification hypothesis in the area of mathematical achievements (in PISA dataset), but showed contrary to predictions that attitudes and affects toward mathematics are more in favour of males (males possess more positive attitudes and affects) in countries with higher gender equity.

The expectancy-value theory of achievement motivation

The expectancy-value theory of achievement motivation (Eccles, 1994; Eccles et al., 1983; Wigfield & Eccles, 2000) focuses on the various groups of factors that create expectation for success in some domain (here: mathematics), and subjective task value, that are proximal predictors of achievement and achievement related choices. The proposed model includes a cultural factors (gender role stereotypes, cultural stereotypes of subjected manner or occupation), socializer's beliefs and child aptitudes as distal causes of achievement-related choices. The mediatory processes includes child's perception of stereotypes and socializer's beliefs, child's self-schema and goals, and elements connected with child's memories or previous experience. A strong interplay between enlisted factors showed the importance of cultural gender-related norms, roles, and stereotypes, and the way these social constructs are reflected in one's self-schema in a self-concepts of one's abilities, ideal self, or preference for specific goals. According to the expectancy-value theory, beliefs about one's mathematical ability and expectancies for success in this area are the strongest predictors for the grade in math among school children, even when the outcomes are controlled for the previous performances (Meece et al., 1990).

Stereotype threat

The stereotype threat effect refers to the concern that is experiences when one feels at risk of confirming, as self-characteristic, a negative stereotype about one's group (Steele & Aronson, 1995; Stelle, 1997). This effect is present in context of underperformance of many minorities and negatively-stereotyped groups, i.e. African-Americans on standardized ability tests (Steele & Aronson, 1995), Latinos on difficult mathematical test (Gonzales, Blanton, & Williams, 2002), white males on athletic performance (Stine, 2002). The stereotype threat effect is also present in mathematical performance and appeared as a decrease of female's level of achievement in the condition of silent gender stereotype, in which the stronger implicit association between math and male become more accessible (Galdi, Cadinu, Tomasetto, 2014; Hausmann, 2014; Nguyen & Ryan, 2008). Gender differences in mathematical performance also occur in environments evoking the gender stereotypes (Beilock, 2008), and that making gender stereotypes salient acts as an amplifier of the stereotype threat effect and results in lowering female's performance in mathematical tasks (Shih, Pittinski, & Ambady, 1999).

The stereotype threat effect (Steele & Aronson, 1995) disappeared when the task is shown to the participants as a gender-neutral (Moè & Pazzaglia, 2006; Spencer, Steele, & Quinn, 1999; Wraga, Helt, Jacobs, & Sullivan, 2007), when the positive stereotypes of in-groups or negative about out-groups was activated before testing (Walton & Cohen, 2003), or the task is presented as a test of feminine superior ability (i.e. perspective taking; Heil, Jansen, Quaiser-Pohl, & Neuburger, 2012). A stereotype threat condition results in about one quarter lower achievements of women than men (Nguen & Ryan, 2008; Picho et al., 2013), but academic domain moderated these effects, so that among STEM (science-technology-engineering-mathematics) students the effect was near zero ($d = 0.06$), while among non-STEM students was significant ($d = -0.25$).

Hausmann (2014; Experiment 1) demonstrated that female science students in the stereotype activation condition perform better than in the non-stereotype condition and female arts students in both stereotype activation and non-stereotype condition. This effect could be a result of stereotype reactance effect (Kray, Thompson, & Galinsky, 2001), which happens when a negative stereotype is activated, and is perceived by the test taker as a limit to their freedom and ability to perform, what lead to behavior that is inconsistent with the stereotype (Nguyen & Ryan, 2008).

Gender identity

Cultural stereotypes about males and females impact the identity of individuals, because gender is one of the most important social category. Bem's (1974) sex-typing theory posits that there are distinguishable dimensions of gender identity: masculinity and femininity, defined as an individual's endorsement to culturally assigned sex traits. Typical male characteristics are: "independence", "acting as a leader", "making decisions easily", whereas typical female traits are:

“understanding”, “warm to others”, and “gentle” (Spence, Helmreich, & Stapp, 1974). Helgeson (1994) reported that masculinity could be treated as an agency, and femininity as a communion (see also Abele, 2003).

Nash (1979) proposed a gender-role mediation hypothesis which states that gender identification may inhibit or promote the optimum level of achievement in cognitive abilities depending on the gender-typed domains of ability. As mechanisms of this model there was specified: gender typing of intellectual domains, gender-role conformity, and self-efficiency beliefs. The similar role to mentioned processes could be also played by the tendency to maintain the congruence between social role, and goals preferences connected with the role, with the pursuit to seek a carrier in math-related disciplines (Diekman & Steinberg, 2013; Evans & Diekman, 2009; Rosenthal et al., 2011).

Signorella and Jamison (1986) found a small but statistically significant association between gender role and mental rotation performance. Kiefer and Sekaquaptewa (2007) demonstrated that women's mathematical performances was correlated with implicit gender-mathematic stereotyping even in the condition of reducing the stereotype threat. Reilly and Neumann (2013) showed that masculinity correlated positively with mental rotation abilities both for females and males, while femininity showed no significant effect on the mental rotation abilities. Franceschini, Galli, Chiesi, and Primi (2014) reported that high implicit gender-mathematical stereotypes results in lower mathematical self-efficiency and mathematical performance among females especially in the stereotype threat condition, but higher in the stereotype lift condition.

Predictors of mathematical performance: Cognitive abilities and math-related self-construals

Ader and Ertkin (2010) conducted an analysis of various predictors of mathematical performance, including several groups of predictors: mathematical background (which refers to the mathematical and mathematical-relevant abilities), anxiety (refers to math and test anxieties), self-regulatory abilities (coping strategies) and self-efficiency. According to their work we can group predictors of mathematical performance in two categories: cognitive abilities factor and belief about one's mathematical abilities factor (anxiety, self-efficiency, and self-confidence). This categorization is not comprehensive. Firmender and colleagues (2014) reported that some elements of studying environment plays an important role in mathematical performance, e.g. teachers' instructional practices.

While exploring cognitive ability factor one should note that mathematical abilities are based on and require both conceptual and procedural competencies that rely on the phonological system, visuospatial system and central executive system (attentional and inhibitory control of information processing) of working memory (Geary, 2004; Kattälä & Lehto, 2008). In the same line of reasoning, Kroesbergen and van Dijk (2015) reported two important precursors of mathematical performance: working memory (especially visual-spatial working memory and central executive; Friso-Van den Bos, Van der Ven, Kroesbergen, & Van Luit, 2013) and number sense („number sense is the ability to quickly understand and manipulate numerical quantities, whether they are processed in a nonsymbolic format [the analog code] or a symbolic format [either verbal or Arabic-visual]"; Kroesbergen & van Dijk, 2015, p. 103). Research showed also that fluid intelligence is involved in mathematical skills (Floyd, Evans, McGrew, 2003; Nunes et al., 2012). Given the stable gender differences in mental rotation ability it should be reported that this ability is treated as an active visuospatial ability, depend on the visuospatial working memory (Cornoldi & Vecchi, 2003). Halpern and LeMay (2000) speculate that male advantage in mathematical task is due to use of the visuospatial strategies in solving mathematical problems. This suggestion was confirmed in the study by Casey, Nuttall, Penzaris, and Benbow (1995).

The second, self-conceptual factor of mathematical performance refers to constructs like mathematical anxiety, mathematical self-confidence (Hyde et al., 1990), self-efficiency (Pajares & Miller, 1994), and attitudes toward mathematics (see Table 4).

Table 4. Gender differences in beliefs about one's mathematical abilities.

Meta-analysis	Belief	Effect size (Cohen's d)
Hyde, Fennema, Ryan, et al. (1990)	Mathematic self-confidence	0.16
	Mathematics anxiety	0.15
Else-Quest, Hyde, & Linn (2010)	TIMMS Self-confidence in Math	0.15
	TIMMS valuaing math	0.10
	PISA extrinsic motivation	0.24
	PISA intrinsic motivation	0.20
	PISA anxiety	-0.28
	PISA math self-concept	0.33
	PISA math self-efficiency	0.33

Note. TIMMS 2003 – Trends in International Mathematics and Science Study; PISA 2003 – Programme for International Student Assessment.

A meta-analysis of Hyde and colleagues (1990) demonstrated that male present more mathematical self-confidence that females (d = 0.18), while female manifest stronger mathematical anxiety (d = -0.15). Pajares and Miller (1994) showed that gender differences in mathematical problems solving was mediated via self-efficiency, with males possess greater self-efficiency and better mathematical achievement. A strong and negative role of anxiety for mathematical performance was confirmed by Ader and Ertkin (2010). Males presented more positive attitudes and affects toward mathematics than females (Hyde et al., 1990). Female attitudes (i.e. math anxiety) and self-construals connected with mathematical abilities are more negative than those of male students (McGraw, Lubienski, & Strutchens, 2006). Results of these studies lead to the conclusion that internalized anxiety which is also connected with implicit and explicit gender stereotypes about lower mathematical abilities of women, could be a strong cause of impairment of females' achievement in mathematics. Given masculinity is connected with greater self-confidence, while femininity with greater compliance and self-control (e.g. Baucom, 1980), gender identity can activate or inhibit a role of belief about one's mathematical abilities.

Aims of the project

The project's aims was twofold. First was connected with the variation in the gender and nationality of the project's participants, who represent three European countries (Austria, Czech Republic, and Poland). Therefore, using the integrative plot-based game, and implementing a participant observation, we were focused on the trajectories of in-groups collaboration, division of the work, and communicational skills. While the participants were gifted students, and the status of science is sometimes linked with self-reliance and individuality, it was a promising opportunity to follow the process of cooperation in the newly developed groups of project's participants.

The second aim was empirical. Yet the study sample was highly accidental, we would like to test three hypothesis. In first hypothesis we postulated that (***h1a***) there are gender differences in visuospatial abilities (mental rotation ability) in favor of males (Voyer, Voyer, & Bryden, 1995), and that (***h1b***) there are gender differences in verbal abilities (verbal fluency) in favor of females (Hyde & Linn, 1988). Thus, we would like to replicate an effect of gender differences in so-called gender-sensitive cognitive abilities. The second hypothesis (***h2***) it was postulated that under stereotype threat condition there will be a stereotype lift effect for males, while the stereotype threat effect for females (Steele & Aronson, 1995). We also tested if masculinity will be positively correlated with cognitive abilities in males and females (***h3***), and what are the correlations between femininity and cognitive abilities (Reilly & Neumann, 2013). Additionally, we examined the associations between cognitive abilities, masculinity, femininity, and performance in the mathematical contest that accompanied the Polish meeting of the Mathematical Duel Plus programme. The analysis is highly explorative, but it also offer the possibility to verify the basic assumptions in the area of gender-mathematical abilities relations in a specific group of highly interested in mathematic adolescents.

Methods

Participant observation

During the integrative game in every group of participants two raters were placed. Each rater lead an observation of group's work using a prepared observation sheet, that raters use to counting cooperative versus competitive behaviors and to estimate a level of participants on the dimensions of domination-submission, warm-cold, and fear. After the individual rating during the group's workshops, both raters discussed their results and prepare short description of group work with special caution to the aspects of cooperation, dealing with communication between nations, and indication of roles played by group members.

Empirical study

After the integrative game, and a break for rest, the session of testing took place. In the same groups as in the integrative game, the participants were seated in order that enable each individual the possibility of focusing on the tasks. In every group the testing lead the same sequence with sex-roles endorsement dimensions of masculinity and femininity, and fluid intelligence tested at first, and the set of other cognitive abilities tested after. More precise description of the study is provided in Procedure section.

Participants

In both observation and empirical phase of the study 44 participants took part (38 males and 8 females) in age between 12 and 19 years, *M* =15,89; *SD* = 1,59. Participants recruited from three countries: Austria (*n* = 9; 7 males and 2 females; 20,45%), Czech Republic (*n* = 21; 16 males and 6 females; 47,73%), and Poland (*n* = 14; 13 males and 1 female; 31,82%). The gender distribution was not random with clear prevalence of males, $\chi2$ (1) = 9,91; p < 0,002. In mathematical contest that accompanies the meeting participants were categorized to three age levels: A (*n* = 17), B (*n* =12), and C (*n* =15). Where possible the scores of participants were connected between study and mathematical contest to obtain a result of mathematical performance in an engaging personally mathematical task.

Measures

Bem Sex Roles Inventory (*BSRI*; Bem, 1974) is a commonly used method to estimate a level of masculinity and femininity (Reilly & Neumann, 2013). In the current study the german version (Schneider-Düker &Kohler, 1988) was used. Because of the lack of comparable versions of BSRI in Polish and Czech populations the adjectives from german version were translated into Polish and Czech by native speakers in both languages, with psychological and pedagogical education (the translation were presented in Appendix). The inventory consist of 60 adjectives: 20 adjectives measure femininity (romantic, dependent, soft-hearted, etc.), 20 measure masculinity (ambitious, strong, brave, etc.), and the next 20 adjectives were bufferr. Each adjective were ranged by participants on the scale from 1 (not at all characteristic of me) to 7 (very characteristic of me). The reliabilities and intercorrelations of the BSRI were presented in Table 5.

Table 5. Reliabilities and intercorrelations between masculinity and femininity scales.

	α Masculinity	α Femininity	$r_{\text{masculinity - femininity}}$
German version	0,85	0,61	-0,68*
Czech version	0,91	0,41	-0,38†
Polish version	0,81	0,78	-0,03
Overall	0,87	0,70	-0,27†

Note. * p < 0,05; † p < 0,10.

Raven Progressive Matrices – Standard Version (TMP-S; Raven, 1956). RPM-SV consist of 5 blocks of 12 task with an increasing difficulty. Basing on the Polish version the instruction was translated into German and Czech. The blocks difficulties for each nation were presented in Table 6.

Table 6. Difficulty coefficients on RPM_SV blocks.

	Austrians		Czechs		Poles	
	female (n = 2)	male (n = 7)	female (n = 5)	male (n = 16)	female (n = 1)	male (n = 13)
Block A	1,00	0,95	0,97	1,00	1,00	1,00
Block B	1,00	0,98	1,00	0,97	0,92	0,98
Block C	1,00	0,95	0,98	0,98	1,00	0,96
Block D	0,96	0,88	0,92	0,94	0,83	0,94
Block E	1,00	0,82	0,90	0,90	1,00	0,88
Overall	0,99	0,92	0,95	0,96	0,95	0,95
r_{age}	-	0,72†	0,00	0,34	-	0,69**

Note. † p < 0.07; ** p < 0.01.

Mental Rotation Test (MRT; Peeters, 1994). MRT consist of 24 tasks in which test taker have to choose two of given four figures that are correct rotations of a stimulus figure. MRT is divided into two parts after a practice session with three set of figures and its rotation. For both 12-tasks parts of the MRT each participant have 2 minutes. A scoring for MRT ranged from 0 to 24. The reliability of MRT is the current study was satisfactory, α = 0,83.

Attention Test d2 (Dajek, 2003; Brickenkamp, 2012). The d2 test consists of 14 series of 47 symbols in each series. Symbols are letters d and p with dashes (one or two) above or below the letter. In each series test takers have to cross out letters that fits the pattern (letter „d" with two dashes, therefore there are three potential correct symbols: d with two dashes above, with two dashes below, or with one dash above and one below the letter). In this test there is a time limit: 40 seconds per each series of symbols. Three scores were used for d2 test: WZ that determines a number of symbols that were screened during the time of the study, B1, which indicates the errors of omission of the correct symbol, and B2, which indicates the errors of false identification of pattern-fitting symbol.

Word fluency test. Participants were invited to enlist as many words beginning with letter „l" (in first phase of the task) and „k" (in the second phase of the task) as possible in the time of 2 minutes. Words could be nouns and including names. A score of this task was a sum of the correct words in the native language of each participant. This task is commonly used in studies of verbal fluency (Hirnstein et al., 2014).

Sociodemographic data. Participants also provided a basic data, about their sex, age. We also obtained the results of the mathematical contest for each participant.

Stereotype threat manipulation. After the BSRI and RPM-SV, participants were manipulated in order to invoke a stereotype threat. We manipulated a stereotype threat by providing participants with a scientific article abstract in which there was a direct information about gender differences in reading, mathematical literacy and science (Reilly, 2012), while in control condition participants were given a scientific article abstract in which there was a description of predictors of mathematical performance without any reference to gender differences (Kattälä & Lehto, 2008). A similar method of stereotype threat manipulation was used in a number of studies of this effect (Nguyen & Ryan, 2008).

Procedure

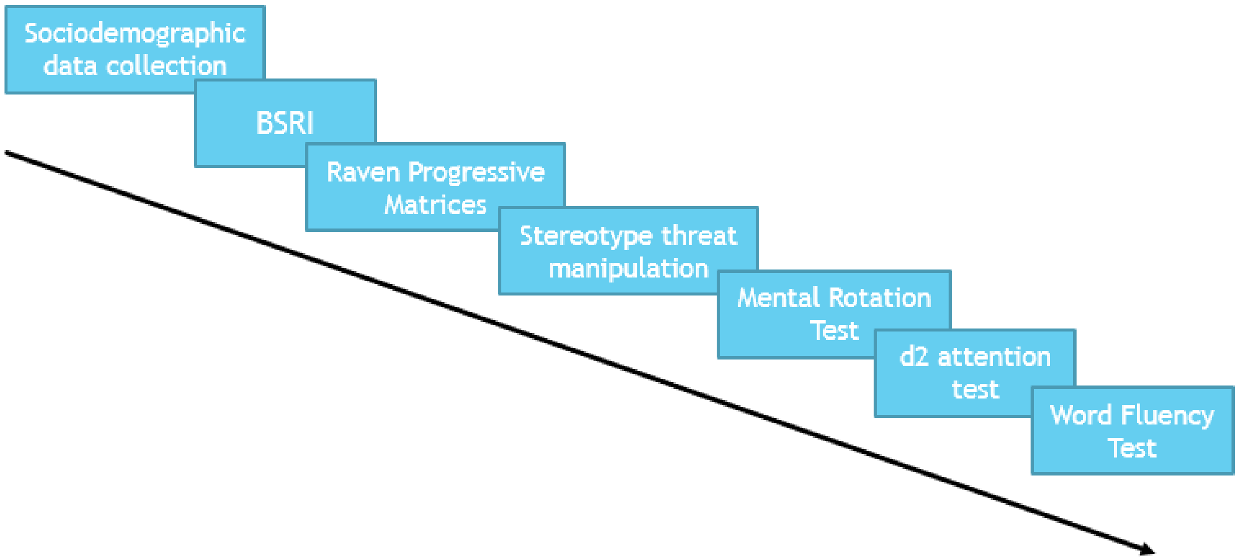
In the first, integrative phase[3] of the study, participants were divided into six groups basing on a stratified selection so to create equal in number and national diversity groups. In those teams, participants were invited to the game based on the „Games of Thrones" novel, in which each team represents some tribe from the novel (Baratheon, Greyjoy, etc.). Each team was seated in a different room, and got its assistant (math undergraduate student), who headed the game activities for the group and assist in the tasks. Tasks consist of ciphers and logic puzzle solving, and enable both

3 The detailed description of the game could be received from the authors of the report after the individual contact.

shared work of the whole group, and the division of work (by partitioning a task). In every group two observers (psychology undergraduate students) were seated with only limited participation in team activities.

The second phase of the study took place in the same rooms and teams as the previous phase. Participants were seated in a comfort distances next to one another , and took part in the testing session according to order presented at Figure 1.

Figure 1. A procedure of the current study.



The order of study was supervised by research assistants (psychology undergraduate students), who read aloud every instruction of tasks and tests, and each time making sure that participants understood the instruction of the consecutive tasks.

Results

Phase 1: Observation of group work

The summary of the observations made during the integrative game are presented in Table 7. The more detailed description is available from the report's authors upon request.

General conclusions that may be drawn from the observation refer to a communication problems which were presented in five out of six groups, and among the large number of project members, and a predominance of males in the position of team leaders. The communicational problems resulted in division within teams in the nationally-oriented subgroups. This pattern was also accompanied with a general tendency to work the solution individually and only discuss it with other members when an individual reach some level of confidence over own solution. The second important conclusion was about the predominance of males in leader roles, and stronger male's inclination to gain a leader role what sometimes resulted in some competitive behaviors. However, his tendency may arise due to the underrepresentation of females in each group. On the other side, an implicit group condition to a member to become leader, was to possess a high level of competence. If the results of the mathematical contest would be taken under consideration, we could conclude that a girl's rather passive inclination, can result in a loss of a team effectiveness. Accordingly, the third conclusion is about the tendency to withdraw among those who feel that their competencies are lacking or unsuitable for a team's work. This tendency, partially caused by language inabilities, also could lead to some information loss during the group process.

Table 7. Summary of group work observation.

Group	Group composition[a]	Initial stage of cooperation	Group cooperation dynamics	Groups effectiveness	Interpersonal relationships
„Tyrell"	5 boys: 3 Czechs, 1 Pole, 1 Austrian 1 girl (Pole)	Troubles with integration and lack of cooperation; Czechs sticks together with a sole girl withdrawn; after the first puzzle was solved individually by one of males, the level of competition in a group of males increased	The individual pattern of work dominated in the team; during the game one subgroup appeared (2 Czechs), which also includes a person who play a role of a team leader. The communication was very limited. Persons proposed one's ideas of solution by writing it on the blackboard without talking over it. The one girl remained withdrawn. When a group had to get a clue which was located outside the room, they went for it together with some amount of enthusiasm. It was also observable that younger participants feel ashamed to propose their solutions.	High engagement in solving a cipher puzzles was seen among males. Team did not ask their assistant for a solution, only after assistant's question they declared a need for help in recollecting some information from a previous lecture which contained the important information about cipher used in the game. Team worked quite fast and effective despite a lack of communication.	There was a moderate level of rivalry between males during team's work, with only limited but increasing level of cooperation.
„Lannister"	7 boys 3 Czechs 2 Austrians 2 Poles 1 girl (Czech)	A sense of being a part of a group was low what partially resulted from language differences. Three members of team withdrew from group activities. One person undertook a role o leader (Austrian).	Teams worked with low cohesion. Two subgroups appeared: one of them contained Austrians and Czechs, while the second recruited two Poles. Within these subgroups there was seen an intellectual stimulation but a coordination of their work was scarce.	Group, despite a low cohesion, was quite effective. Team members ask the assistant for cues. The group's work was in large extent coordinated by a group leader who presented high level of competencies, what was seen by other participants.	The amount of affiliative acts was increasing with a little number of competitive behaviors (between Poles). Czechs provide much emotional support to other participants with important role of one girl in this aspect.
„Targaryen"	6 boys 2 Czechs 1 Austrian 3 Poles 1 girl (Czech)	A group communicated successfully from the beginning of the game. Conversations	In this team there was a division of labour in the tasks, what helped in controling time, and led this team to success in whole game. A male-female pair	A team work with a high effectiveness, mainly due to the partitioning of the tasks. Assistant's help was used in order to	A large number of affiliative acts were observed: explaining, discussion over

		were made in English. An active role was played by one of the males (Czech), who was joking, proposing a solutions, asking others for a advice. One member was clearly an outsider.	appeared and showed a lot of interest to each other. A male member of this subgroup played also a role of a leader in the game. One male had a language problem. Solutions were consulted in team with a required time for work in salience.	get a deeper insight into the rule of ciphers used in the tasks.	a problem, laughing and joking, „high-fives”.
„Baratheon”	7 boys 3 Czechs 1 Austrian 3 Poles 2 girls 1 Austrian 1 Czech	In the initial stage of the game the highest engagement was shown by the group of three Czechs (2 boys and girl), and one Pole with a quite active role of an Austrian girl. One Czech and one Pole demonstrated dominative behaviors, also with a strong role of Czech girl. Pole boys were withdrawn somehow, and the youngest member – Austrian seemed to be insecure.	The team work with increasing level of enthusiasm and cooperation, but there was clearly seen a pattern of group disintegration, with two Poles and one Austrian only aspiring to help. The main part of the work was done in a team of 3 Czechs, 1 Pole and 1 Austrian girl. The subgroups were working solutions in their own languages and then presented them to others in English.	The group manifested a differential level of effectiveness according to a type of puzzle. The attempts to partition the tasks weres scarce but took place , and teams work as a whole for the most of the time . The team only occasionally asked their assistant for help.	Affiliative behaviors were manifested quite frequently, not only within the subgroups, but also between subgroups, e.g. a Czech boy handed a paper to an Austrian girl asking to contribute. There was a lack of competitive behaviors. Some affiliative attempts of the members with lower engagement were ineffective.
„Greyjoy”	4 boys 2 Czechs 1 Pole 1 Austrian 2 girls (Czechs)	In an initial stage of team work there was a very limited tendency to cooperate. One of the Czech males undertook a leader role.	During the game a Pole try to join a Czechs leader, but the Pole showed a large number of competitive behaviors. One Czech withdrew from the game, two Czech girls worked together, while one Austrian manifested some fear and also worked alone. Members used Polish and Czech in communication, with English used only in communication with an Austrian. There were difficulties to understand one other. The flow of information flow was smooth.	A team's work was quite effective. Thesolutions were at first made in subgroups, and next presented to other members and agreed. The leader asked an assistant for help several times. Two members was the most effective.	Affiliative behaviors were presented at the beginning of the game. A little amount of competitive behaviors were demonstrated between two candidates to leader roles.
„Stark”	7 boys 3 Czechs 1 Austrian 3 Poles	In the beginning of the game the team splits into the national	A team was still divided into a subgroup that worked on the tasks (Czechs and Austrians), and the	Despite a low number of really working members a team was effective	In the team's work there is a lack of attempt to deepen the

	1 girl (Austrian)	subgroups within which members speak their own languages. The propositions of solutions, after anagreement reached within a small subgroup was presented in English to other participants. A Polish subgroup withdrew because of lack of abilities connected with solving ciphers.	uninvolved rest. One of the Czechs male was communicatively very competent what helped him in cooperation with Austrians, two remaining Czechs took part in the task solving by communicating with their Czech colleague. Poles showed a moderate level of interest only in the first task, but with the increasing level of cipher's difficulty they withdrew.	and worked fastly. The group did not ask for assistant's help.	relationships. Affiliative act were presented among three members who really works on the solutions (with a little number of disagreements but with an ability to admit to the mistakesr).

Note. [a] – a different size and composition of groups results partially from the absence of some project participants during the meeting.

Phase 2: Cognitive abilities testing

Descriptive statistics

Means, standard deviations and distribution coefficients of variables examined in the current study are presented in Table 8.

Table 8. Descriptive statistics for examined variables.

	M	*SD*	*min - max*	*skeweness*	*curtosis*	$W_{\text{Shapiro-Wilka}}$
RPM-SV	57.14	3.09	48 – 60	-0.64	0.99	0.92**
MRT	14.05	4.21	2 – 22	-0.59	0.71	0.97
WZ	491.27	139.45	88 – 653	-1.25	1.22	0.88***
B1	54.38	66.10	0 – 267	1.63	2.21	0.77***
B2	8.02	20.62	0 – 110	4.18	17.89	0.40***
Word fluency	13.20	3.71	5,50 – 22,50	0.34	0.67	0.97
Femininity	4.41	0.58	2.85 – 5.30	-0.89	0.30	0.93*
Masculinity	4.71	0.79	3.10 – 6.45	0.10	-0.37	0.98

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The results of Progressive matrices works as a test of general cognitive abilities of students participated in the study. Using Polish normalization of PMT (Jaworowska & Szustrowa, 1991a, b), the average level of performance in PTM was in 98th percentile, therefore we can conclude that students participated in the study was highly intelligent. A dispersion of results in other cognitive abilities is high, negative skewness suggest that in a sample there is a prevalence of higher results in fluid intelligence, mental rotation ability and total symbols screened in the attention test.

Cognitive abilities: effects of gender and nationality

The hypothesis **h1a** and **h1b** were tested in 2 (gender) x 3 (nationality) ANOVA (and also in non-parametrical Mann-Whitney's test and Kruskal-Walise). For fluid intelligence (RPM) the main effect of gender was insignificant, $F(1, 40) = 0.37$; $p < 0.55$; $\eta_p^2 = 0.009$; $U = 127.50$; $Z = -0.49$; $p < 0.62$. Similarly, the main effect of nationality was insignificant, $F(2, 40) = 0.84$; $p < 0.44$; $\eta_p^2 = 0.04$; $H(2; N = 44) = 0.81$; $p < 0.67$. The interaction between gender and nationality was also insignificant, $F(2, 38) = 1.53$; $p < 0.23$; $\eta_p^2 = 0.07$. We also conducted an inspection of the variance ratios (VR). According to the greater male variability hypothesis, VR in RPM was 1.73, what means that male's variability was larger than female. Thess results should be treated with caution because of the greater number of men than women in the study.

In MRT the main effect of gender was insignificant, $F(1, 40) = 1.39$; $p < 0.24$; $\eta_p^2 = 0.03$; $U = 99.00$; $Z = 1.36$; $p < 0.17$, but the main effect of nationality was significant, $F(2, 40) = 5.37$; $p < 0.009$; $\eta_p^2 = 0.21$; $H(2; N = 44) = 8.66$; $p < 0.01$, and post-hoc testes revealed a significant difference between Czech score ($M = 12.43$; $SD = 4.21$), and Austrian score ($M = 17.44$; $SD = 3.24$), $Z = 2.93$; $p < 0.01$. There interaction was insignificant, $F(2, 38) = 0.29$; $p < 0.75$; $\eta_p^2 = 0.01$. Again, VR was found to be greater than 1.00, so the variability of result in this ability was higher among males than among females.

In attention test we found no significant main effect of gender in WZ, $F(1, 38) = 1.38$; $p < 0.20$; $\eta_p^2 = 0.04$; $U = 102.50$; $Z = -0.95$; $p < 034$, and B2, $F(1, 37) = 0.24$; $p < 0.63$; $\eta_p^2 = 0.009$; $U = 111.50$; $Z = -0.78$; $p < 0.43$. The marginally significant gender effect was found for B1, $F(1, 36) = 3.15$; $p < 0.08$; $\eta_p^2 = 0.08$; $U = 56.50$; $Z = 2.53$; $p < 0.01$. Males ($M = 64.56$; $SD = 69.61$) scored higher that females ($M = 11.13$; $SD = 10.27$). There were no significant effects of nationality in every attentional score, $Fs < 2.00$; $p > 0.10$; $Hs < 3.79$; $p > 0.15$, and the interaction effects.

Nor main gender effect, $F(1, 32) = 0.04$; $p < 0.84$; $\eta_p^2 = 0.001$; $U = 80.00$; $Z = -1.42$; $p < 0.15$, neither nationality, $F(2, 32) = 1.50$; $p < 0.24$; $\eta_p^2 = 0.09$; $H(2; N = 38) = 0.71$; $p < 0.70$, and interaction, appeared for verbal fluency.

The results are presented in Figure 2 and in Table 9.

Figure 2. Cognitive abilities per gender and nationality (error bars refers to standard errors) .

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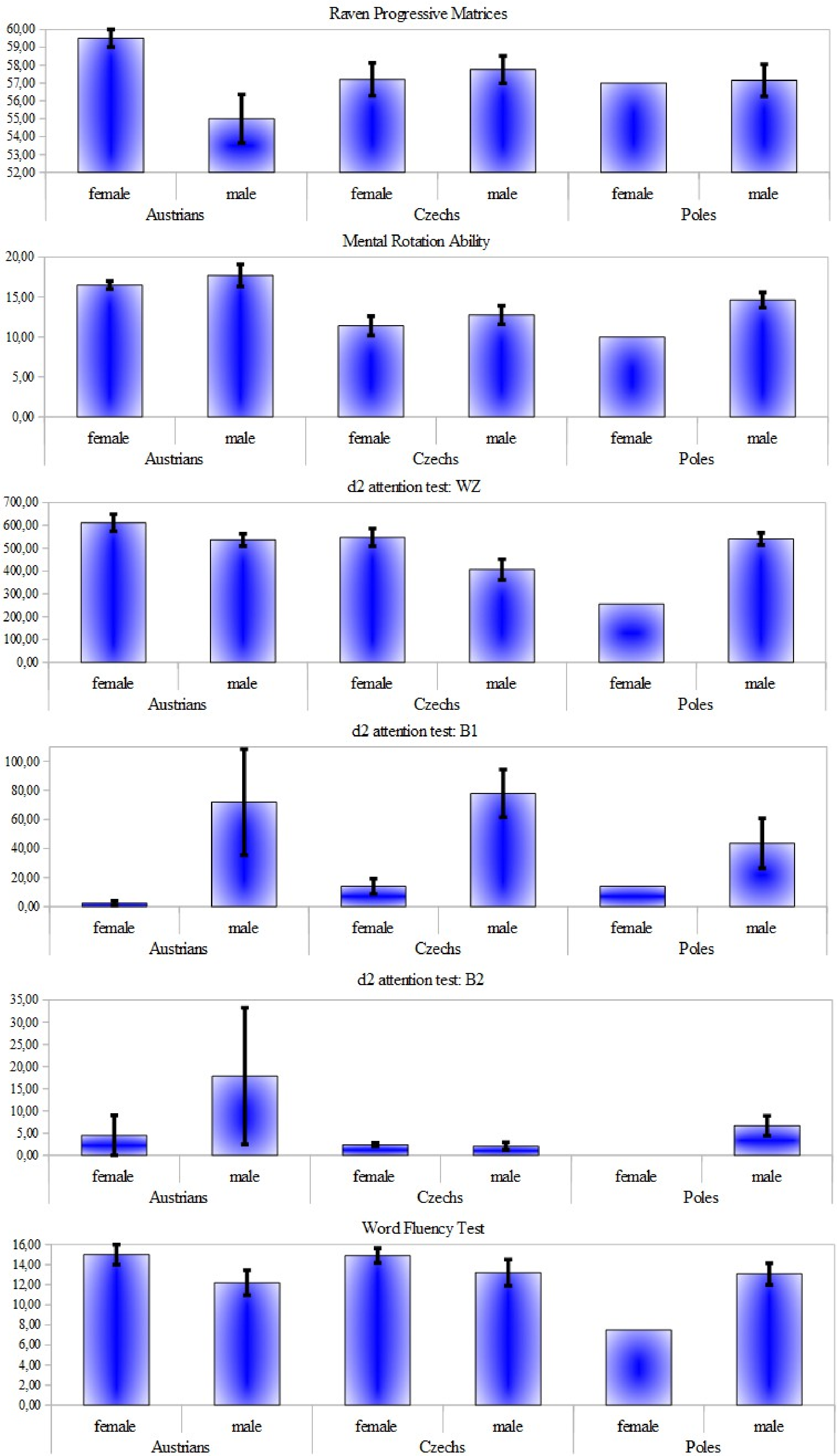
Raven Progressive Matrices
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Poles
Mental Rotation Ability
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Word Fluency Test
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female
male
Austrians
Czechs
Poles

Table 9. Gender differences and variability ratio (VR) in cognitive abilities

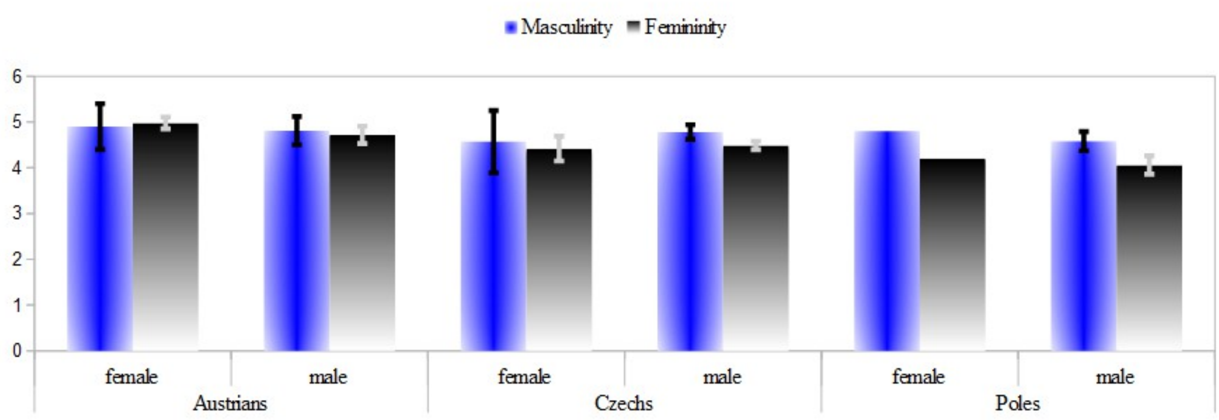
	Male	Female	Cohen's *d*	*VR*
Fluid intelligence (progressive matrices)	57.00 (3.30)	57.50 (1.91)	0.24	1.72
Mental rotation ability	14.39 (4.36)	12.50 (3.25)	0.45	1.34
WZ	468.44 (162.21)	526.88 (132.58)	-0.42	1.22
B1	64.56 (69.61)	11.13 (10.27)	0.81	6.78
B2	6.94 (19.05)	12.63 (27.35)	-0,28	0.70
Verbal fluency	12.98 (3.90)	14.00 (2.95)	-0.27	1.32

Note. Numbers in parenthesis refers to standard deviations.

Femininity and masculinity: effects of gender and nationality

The MANOVA was used to examine themain effects of gender and nationality on the scores of femininity and masculinity. The main effect of gender was insignificant, Wilk's $\lambda = 0.99$; $F(2, 39) = 0.03$; $p < 0.97$ for masculinity, $F(1, 40) = 0.05$; $p < 0.83$; $U = 138.50$; $Z = 0.15$; $p < 0.88$, and for femininity, $F(1, 40) = 0.03$; $p < 0.83$; $U = 117.00$; $Z = -0.81$; $p < 0.42$. The main effect of nationality was significant, Wilk's $\lambda = 0.75$; $F(2, 39) = 2.99$; $p < 0.02$ but due to femininity, $F(2, 40) = 5.03$; $p < 0.01$; $H(2; N = 44) = 8.39$; $p < 0.02$, not for masculinity, $F(2, 40) = 0.26$; $p < 0.77$; $H(2; N = 44) = 0.24$; $p < 0.89$. Significant differences in femininity were found between Austrians ($M = 4.78$; $SD = 0.46$) and Poles ($M = 4.07$; $SD = 0.68$), $Z = 2.88$; $p < 0.01$. There were no significant effect of interaction. The results are presented in Figure 3.

Figure 3. Femininity and masculinity per gender and nationality.



Stereotype threat manipulation

Due to verify the hypothesis h2, for a abilities tested after the stereotype threat manipulation was implemented (MRT, WZ, B1 and B2, and verbal fluency) two independent analyses were conducted: 2 (gender) x 2 (stereotype threat vs. control) ANOVA and 3 (nationality) x 2 (stereotype threat vs. control) ANOVA. In both analyses the main effect of manipulation was insignificant, Wilk's $\lambda > 0.80$; $Fs < 1.12$; $p > 0.38$, and there was no significant interaction between stereotype threat condition and gender, Wilk's $\lambda > 0.72$; $Fs < 1.00$; $p > 0.63$. It could be concluded that the manipulation of stereotype threat was ineffective. Means and standard deviations for the main effect of stereotype threat manipulation are presented in Table 9.

Table 10. Cognitive abilities in a group of control and stereotype threat condition.

	Control condition		Stereotype threat condition				
	M	*SD*	*M*	*SD*	*t*	*U*	*Z*
MRT	14,90	3,38	12,80	4,65	1,63	157,00	1,15
WZ	473,00	151,43	482,40	172,94	-0,18	159,50	-0,84
B1	49,35	59,18	51,95	68,54	-0,12	169,50	0,81
B2	2,60	3,14	13,81	28,95	-	168,00	-0,87
Fluency	13,21	3,44	13,81	3,89	-0,46	135,50	-0,28

Gender identity and cognitive abilities

The correlation analysis was performed between femininity, masculinity, and cognitive abilities. The results of the analysis with control of gender and experimental condition were presented in Table 11.

Table 11. Femininity, masculinity, and cognitive abilities.

	Femininity			Masculinity		
	r	r_{gender}	$r_{condition}$	r	r_{gender}	$r_{condition}$
RPM	-0,03	-0,04	–	0,05	0,05	–
MRT	-0,02	0,01	-0,04	0,11	0,11	0,09
WZ	-0,08	-0,09	-0,07	-0,27†	-0,27†	-0,26†
B1	-0,02	0,01	-0,02	-0,14	-0,16	-0,14
B2	0,10	0,09	0,13	-0,19	-0,19	-0,17
Fluency	-0,03	-0,04	-0,03	0,06	0,06	0,07

Note. † $p < 0.09$.

Both parametrical (Pearson product-moment correlation) and nonparametrical (Spearman coefficient) yielded similar results, therefore we interpret a parametrical correlations. Only marginally significant negative correlation was between masculinity and WZ. Additional analyses carried out among males and females showed that there is a strong in magnitude, yet insignificant due to number of female (n = 8) positive correlation between masculinity and MRT, $r = 0.51$; $p < 0.20$, and between femininity and WZ among females, $r = 0.59$; $p < 0.12$. Among males there was a marginally significant correlation between masculinity and B2, $r = -0.32$; $p < 0.07$.

Gender identity, cognitive abilities and performance in mathematical contest

We also conducted a series of correlational analyses for scores that participants yielded in the mathematical contest. Independent analyses were conducted for each level of contest. The results of the analyses are presented in Table 12.

Table 12. Cognitive abilities, gender identity, and mathematical performance.

	Level A (*n* = 17; 2 female)	Level B (*n* = 12; 4 female)	Level C (*n* = 15; 2 female)
RPM[a]	0.55* / 0.54*	0.01 / 0.05	0.40 / 0.43
MRT	-0.36	-0.01	0.04
WZ	-0.05	-0.42	0.26
B1	0.14	0.05	-0.20
B2	-0.02	0.63*	-0.34
Fluency	-0.07	-0.60†	0.18
Femininity[b]	-0.45† / -0.32	-0.21 / -0.19	-0.64* / -0.72**
Masculinity[b]	-0.09 / -0.06	0.36 / 0.65†	0.46† / 0.53†

Note. [a] – after a slash there is a correlation controlled for age; [b] – after a slash there is a correlation controlled for gender, nationality, and the second dimension of gender identity; † $p < 0.10$; * $p < 0.05$; ** $p < 0.01$.

The conducted analysis showed a pattern of rather nonsignificant effects of cognitive abilities (mental rotation, attention, and verbal fluency), and only limited confirmation of positive correlation between fluid intelligence and mathematical performance. Gender identity dimensions showed a pattern of rather positive, yet only marginally significant correlations between masculinity and mathematical performance, and rather negative correlations between femininity and mathematical performance.

Discussion

The current study aims was (1) a replication of gender differences in cognitive abilities, in particular, in the mental rotation ability and verbal abilities, that was recognized as a gender-sensitive abilities (Hyde, 2005; Neisser et al., 1996; Voyer, Voyer, & Bryden, 1995), (2) to examine a role of stereotype threat manipulation for performance of student, who are highly intelligent and interested in mathematics, and to (3) examine a role of gender identity dimensions of masculinity and femininity for cognitive abilities and mathematical performance.

The results obtained in the study correspond with the gender similarities hypothesis (Hyde, 2005) considering a lack of significant main effect of gender in each one of tested cognitive ability (fluid intelligence, mental rotation, verbal fluency, attention). However, it was also confirmed that variability of males results are higher than females ($VR > 1.00$), what is in line with greater male variability hypothesis (Hyde & Mertz, 2009). Although the greater male variability hypothesis is used to explained an asymmetry in number of males compared to females in the highest level of mathematical abilities, in the current study the found difference in variability of scores did not translate into a significant difference in the level of abilities. One of the potential reasons of this observation could lie in the high disproportion between males and females in the sample (4,5:1). Such a disproportion could result in highly selective attendance of female participants, what is also reflected in the lack of gender differences in masculinity and femininity, that are commonly appearing in studies in different samples of adolescents and young adults (e.g. Johnson et al., 2006).

Nationality was not a significant predictor of cognitive abilities level, except for a mental rotation ability, in which there was found a significant difference between Austrians and Czechs. This singular difference could be an effect of some dissimilarity in the focus put on the learning of geometry in mathematical curriculum during primary and secondary school. However, a magnitude of this differences with reference to lack of other cross-national differences, could lead as to a conclusion that the found difference is rather negligible. The nations participated in the current project are rather similar in the gender equity (see Table 3), therefore the insignificant interaction terms of gender and nationality in ANOVAs for cognitive abilities could be in concordance with a gender stratification theory (Baker & Jones, 1993). One should also keep in mind that this interpretation should be treated with caution because of a little number of tested countries, that also represent a highly similar geo-political location (in mid-Europe).

A stereotype threat manipulation (Steele & Aronson, 1995) was inefficient in the current study. One of the potential explanation could be that a gender roles of participants were rather masculine-saturated that feminine, and only moderate in magnitude. According to the results of Franceschini, Galli, Chiesi, and Primi (2014), the stereotype threat has a more powerful impact among those female who endorse strong gender stereotypes. While in the current study a gender-role were closer to neutral (means were at level of 4.00 in the scale range from 1 – not characteristic of me to 7 – very characteristic of me) the stereotype threat manipulation could have lower impact. The second interpretation is connected with highly selective, as was stated above, sample of women in the participants of the current project. Females who decided to join the project, knowing that there will be prevalence of male attendand may present greater resistance to gender-related pressures, which are causes of potential lower achievement of female in a gender-sensitive abilities (Nash, 1979). The last argument is statistical. The low number of female participants could result in a low power of the study to reveal a significant effect size for stereotype threat manipulation.

Although, hypothesis about a positive correlation between masculinity and cognitive performance was not confirmed (yet a positive role of masculinity for females achievement in MRT was noticed), the significant correlations were found between both femininity (negative), and masculinity (positive) with the mathematical performance in situation of mathematical contest. The last result can be interpreted also in the light of the stereotype threat paradigm. A mathematical contest could be a highly tension-invoking and also gender-activation situation, which could activate interpersonal beliefs about one's endorsement of feminine and masculine roles, that may also affect the way of dealing in the competitive context. Masculine traits endorsement was positively correlated with mathematical performance, what is in line with a results of Reilly and Neumann (2013) meta-analysis. Femininity appeared to be negatively correlated with mathematical performance, what could be partially mediated by possible greater tendency of highly feminine participants to experience concerns and lack of self-confidence – that are stereotypically feminine traits – which are also negative predictors of math performance (Ader & Ertkin, 2010).

The current study although limited by low little number of participants, and strong gender disproportion, brought some new results that are in corroborance with a commonly adopted hypothesis about gender differences in cognitive abilities and mathematics. The advantage of the study is also that participants were highly intelligent. In such a group neither gender differences in any cognitive ability (even gender-sensitive), nor the stereotype threat effect occurred. However, there was shown that the role of gender identity dimensions of masculinity and femininity play a substantial role in real life mathematical performance in competitive settings.

Conclusions

1. A work in multinational groups was rather difficult for participants of the Mathematical Duel Plus programme, and the main cause of these difficulties lies in a language incompatibility. Teams in which members had high language abilities (communicatively use English) were the most effective.

2. Although, the affiliative tendencies in multinational teams was visible, often a pattern of withdrawal was observed (especially based on language communication problems), while the only competitive behaviors appears between males who compete to a leaders roles.

3. Among highly intelligent participants of the programme gender differences in gender-sensitive cognitive abilities (mental rotation, verbal fluency) were not present.

4. Stereotype threat manipulation was ineffective, and did not result in decrease of female's performance of increase of male's performance.

5. Gender identity dimensions were not correlated with cognitive abilities (only exception concerned a range of screened symbols in attention task, where masculinity was negatively correlated with attention), but masculinity and femininity do correlate with performance of participants in the mathematical contest.

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Appendix. BSRI language versions (*next page*)

German	Polish	Czech
Masculine adjectives		
hat Führungseigenschaften	ma cechy przywódcze	má vůdčí schopnosti
tritt bestimmt auf	ma silną wolę	má silnou vůli
ehrgeizig	ambitny	ambiciózní
respekteinflößend	groźny	impozantní
kann andere kritisieren, ohne sich dabei unbehaglich zu fühlen	może krytykować innych bez skrepowania	může bez zábran kritizovat ostatní
verteidigt die eigene Meinung	broni własnej opinii	je zastáncem svého názoru
entschlossen	zdecydowany	rozhodný
sachlich	rzeczowy	konkrétní
nicht leicht beeinflußbar	nie poddaje się wpływom, trudno na niego wpłynąć, nie ulega wpływom innych	neoblomný
unerschrocken	nieustraszony/nieposkromiony	nebojácný
intelligent	inteligentny	inteligentní
hartnäckig	zawzięty, uparty	svéhlavý
ist bereit, etwas zu riskieren	skłonny do podejmowania ryzyka	rád riskuje
kraftvoll	silny	silný
furchtlos	nie jest bojaźliwy	nebojácný
scharfsinnig	spostrzegawczy	vnímavý
wetteifernd	skłonny do rywalizacji	soutěživý
sicher	pewny	sebejistý
zeigt geschäftsmäßiges Verhalten	Nastawiony na sukces	nastavený na úspěch
konsequent	konsekwentny	důsledný
Feminine adjectives		
romantisch	romantyczny	romantický
abhängig	zależny	závislý na něčem, někom
weichherzig	o miękkim sercu	má měkké srdce

glücklich	szczęśliwy, zadowolony	šťastný
bemüht sich, verletzte Gefühle zu besäftigen	nie chce ranić uczuć innych osób	nechce ublížit pocitům druhých osob
feinfühlig	wrażliwy	citlivý
sinnlich	zmysłowy	smyslný
fröhlich	wesoły	veselý
nachgiebig	pobłażliwy	shovívavý
bescheiden	skromny	skromný
empfänglich für Schmeicheleien	podatny na pochlebstwa	rád lichotí
empfindsam	czuły	citlivý
selbstaufopfernd	ofiarny	obětní
benutzt keine barschen Worte	nie używa ostrych słów	nepoužívá hořká slova
verspielt	figlarny	hravý
verführerisch	uwodzicielski	svůdný
achtet auf die eigene äußere Erscheinung	zwraca uwagę na własny wygląd	pečuje o svůj vzhled
leidenschaftlich	namiętny	vášnivý
herzlich	serdeczny	srdečný
liebt Sicherheit	lubi czuć się bezpieczny	rád se cítí v bezpečí

Neutral adjectives

gesellig	towarzyski	společenský
nervös	nerwowy	nervózní
gesund	zdrowy	zdravý
steif	drętwy	strnulý
gründlich	dokładny	přesný
teilnahmslos	apatyczny	apatický
vertrauenswürdig	godny zaufania	důvěryhodný
überspannt	ekscentryczny	excentrický
zuverlässig	niezawodny	spolehlivý
unpraktisch	niepraktyczny	nepraktický
fleißig	pilny	pilný
niedergeschlagen	przygnębiony	skleslý
geschickt	zręczny	obratný
eingebildet	zarozumiały	nafoukaný

gesetzestreu	karny, lojalny	trestní , loajální
stumpf	naiwny	naivní
gewissenhaft	sumienny	svědomitý
unhöflich	nieuprzejmy	hrubý
aufmerksam	uważny	pozorný
vergeßlich	zapominalski	zapomnětlivý