

Similar But Different?

Cognitive Differences in the Discussion of Women in Science and Technology

ILONA HORWATH, NICOLE KRONBERGER, MARKUS APPEL

INTRODUCTION

Recent years have seen a growing interest in increasing the proportion of women in science and technology (see OECD, 2008), motivated by economic considerations and/or policies to promote gender equality. A recurring topic in pertinent discussions has been the question whether gender differences in cognitive skills could be a reason why women, despite numerous initiatives, continue to be underrepresented in technical fields – certainly a very sensitive issue.¹ While some condemn the question itself as outrageous, others ask why women should be “pushed” into fields that do not appeal to them. In line with Ceci and Williams (2009) we think that there is a need for a more sober discussion that takes into account the impressive body of research that accumulated over recent years.

These discussions often focus on the question of whether gender differences actually exist or not. As we will show, the results of numerous studies on cognitive gender differences are multifaceted and highly nuanced. Thus, it is not hard to find studies that can be cited to support any given standpoint, and the discussion quickly starts going in circles. Furthermore, a politically

1 | A well-known example is a 2005 speech by the then-president of Harvard University on the underrepresentation of women in science and technology, which created a worldwide stir. His elaborations on ability differences among top achievers provoked a storm of indignation, but they also launched more nuanced efforts to address the issue (see, for example, Ceci and Williams, 2007; Nature Neuroscience, 2005).

motivated point of view often in many ways hampers a sober assessment of the results. Especially in recent years, though, we have witnessed the emergence of interesting research results in several respects. In particular, the publication of meta-analyses that summarize and evaluate the results of many studies, new studies in the field of stereotype research, and the consideration of new issues (such as whether gender differences in the cognitive area are stable or subject to change) have delivered new impetus to the discussion.

Even if the empirical findings continue to indicate a complex pattern of similarities and differences between men and women, we endeavor in this paper to summarize the research results in a kaleidoscopic way. We begin by questioning the role of competence for the stereotypical perceptions of men and women, and discuss what this means with respect to questioning women's aptitude for technical fields. We then survey the current state of research on gender-specific cognitive differences, taking into account various interpretations offered for the results. Finally, we shift perspective away from considering whether there are gender differences in cognitive abilities and raise the pragmatic question of whether cognitive abilities can be influenced and, if so, how. We strongly favor fostering this perspective shift in the discussion as a whole. We are convinced that this can save energy, prevent frustration, and create a constructive climate among the various protagonists.

STEREOTYPES ABOUT WOMEN IN SCIENCE AND TECHNOLOGY

What stereotypes exist?

“It seems to me that in the beginning women are always grossly underestimated.” (Female student)

“Even before I started, they said: A woman in computer science, forget it.” (Freshman coed)

These quotes from a group discussion we conducted for our study² illustrate how female college students perceive the assessment of their competence. An

2 | In TEquality – Technik.Gender.Equality, we investigated factors that influenced whether students were successful in or dropped out of the computer science and mechanics programs at a Middle European University. On the basis of our findings, we de-

openly articulated, universal denigration of women has now become generally unacceptable (Eckes and Six-Materna, 1998); nevertheless, stereotypes about the purported nature of gender differences – e.g. that men have superior mathematical-technical abilities – tenaciously persist.

Gender stereotypes are cognitive structures that convey socially shared assumptions and/or a culturally shared understanding of characteristic qualities of men and women (Eckes, 1997). As recent stereotype research shows (e.g. Cuddy et al., 2008; Fiske et al., 2002; Glick and Fiske, 2001), attributions of particular abilities or the lack of them constitute a substantial portion of many stereotypes. Viewing prejudices as exclusively negative judgment passed on a group usually misses the mark by failing to take into account the fact that the powerful influence of many stereotypes in everyday life is due precisely to the fact that they combine positive and negative views of a group.

Two dimensions are especially significant in connection with group stereotyping: In addition to the matter of competence, the ascription of social warmth (in the form of friendliness, helpfulness, a caring nature) also has particular significance. The combination of these two dimensions makes it possible to differentiate among four groups of stereotypes, each one of which elicits specific prejudicial dynamics and is also connected with specific feelings and behavioral options (Cuddy et al., 2008). This differentiation highlights that a particular stereotype does not necessarily apply to all women, and that they are frequently confronted by ambivalent stereotypes that combine positive and negative attributions (competent-but-cold versus warm-but-less-competent). The competent-but-cold ascription is often accompanied by clear antipathy, whereby certain groups of women are considered to be a real threat (e.g. they are said to be able to or want to control men). Attributing social warmth and simultaneously reduced competence, on the other hand, is usually paired with a paternalistic attitude (Glick and Fiske, 2001). In our study, we were able to observe that successful female students were said by their fellow students to be less socially warm and less attractive in a feminine way but extremely ambitious. It is alarming that these women experience a lower degree of social ac-

veloped recommendations designed to improve conditions for students and increase the proportion of women among them (see www.tequality.at and Horwath et al., 2006, 2007). Data collection comprised both group discussions with current and former students of computer science and mechatronics and a questionnaire to survey everyone who had registered for either of these two programs between 1993 and 2006.

ceptance and feelings of belonging in the academic environment (Kronberger and Horwath, forthcoming).

The paternalistic attitude is significantly more socially acceptable, since women are thereby portrayed as wonderful beings (possibly with social, cultural, and artistic gifts). The fact that this – at least implicitly – goes along with negation of their competence is something of which both sides are often not consciously aware. But this is precisely why this subtle form of prejudice can be so insidious. People who think this way are usually convinced that they are positively disposed towards women (subjective benevolence), and women who are confronted by this attitude often do not even perceive it as sexist or discriminatory. Rather, studies suggest that women usually have a hard time categorizing these attitudes; they find them somewhat perplexing (Rudman and Glick, 2008). When implicit denials of competence are expressed in combination with praise, this can have a disarming effect.

Many of the women we surveyed in our study also maintain that they have hardly experienced open discrimination and sexism. More frequently, they report experiencing implicit denials of their competence, more often expressed in deeds than in words – for instance, when women relate that men in their age group are quite helpful and gladly provide explanations about course material; conversely, these women are also aware that men – even younger men – hardly ever approach them with questions. Are they not considered likely to know the answer? Women also report experiencing denials of their competence cloaked in a compliment:

“It’s like, when people come to me and say ‘Hey, you’re a woman and you’re studying computer science. Wow, super achievement!’ ... Men study mechatronics or computer science and that’s just normal, but in my case it’s an outstanding accomplishment. And I get this kind of funny feeling, because no way is that a real compliment. It’s sort of a mixed message, both positive and negative.” (female student)

Of course women feel flattered when they are praised as extraordinary; nevertheless, this praise is also confirmation that the ‘women are not technically gifted’ stereotype is still very much alive, whereby it must also be emphasized that women, too, not infrequently share this view.

The paternalistic approach of bringing goodwill to encounters with women while subtly disparaging their capabilities is also referred to as benevolent sexism (Glick and Fiske, 1996). For the recipients, this ambivalent attitude is

considerably harder to interpret than open deprecation and/or sexist hostility. Naturally, it might seem more pleasant to be confronted by benevolent sexism than with its antagonistic counterpart, but studies indicate that a denial of competence in the form of benevolent sexism can have a particularly deleterious effect on women's performance. In a series of experiments by Dardenne et al. (2007), for example, female jobseekers, prior to taking a test, were confronted by sexist remarks of either a benevolent or hostile nature. Although the benevolently sexist statements were not perceived as sexist by most of the women, four experiments indicated poorer performance under conditions of benevolent compared to hostile sexism. Women who encountered benevolent sexism had to struggle with confusing thoughts about their own competence. This brings us to the question of how stereotypes and the expectations of competence associated with them actually work in everyday life.

How do stereotypes work?

“The feeling for technology that you get from your parents as part of your upbringing is what they (women) actually lack. And this is a bit of a shortcoming.” (male student)

Many studies examine the question of how expectations of parents, caregivers, and teachers influence children's behavior and performance (see Lloyd and Duveen, 1992; Tiedemann, 2000). That such influences exist was highlighted long ago by Rosenthal and Jacobson's influential 1968 study on the Pygmalion Effect. This study showed that when teachers are told that some randomly selected students would soon excel, these students' performance (as measured by objective tests) indeed improved more than other students' performance. Later research on the relationship between expectation and achievement is more controversial but it is interesting to scrutinize the literature for gender issues.

For example, Ziegler et al. (1998) found that 27% of mathematics teachers and over 30% of physics instructors rated boys as more gifted than girls. Accordingly, there is a relatively high probability that a girl will encounter a teacher who attributes less talent to her than to a boy. An older study by Roloff and Evertz (1992; see Roloff, 1999) shows how girls' chances to succeed in physics and computer science are utterly thwarted by teachers' implicit conviction that this subject matter will not be used on a highly qualified level in these girls' lives, and how identical behavior by girls and boys in classroom situations is variably interpreted in accordance with the stereotype 'boys are

good; girls are diligent' (on the subject of this interpretational pattern, also see the meta-analysis by Swim and Sanna, 1996). A similar pattern of competence ascription was also sketched by Menacher (1994), whereby mothers attribute their daughters' good grades in mathematics to studying hard, whereas their sons are said to have obtained good grades because they are gifted. Crowley et al. (2001) observed parents and their children in museums and discovered that scientific objects on display were explained three times more often to boys than to girls.

But parents and educators are not the only ones who influence youngsters; young people make a major impact on each other. Even children regard mathematics as masculine (J. Steele, 2003), and girls are less frequently encouraged to participate in scientific activities by their peers than boys are (Stake and Nickens, 2005). Hyde et al. (1990) report that young people as well engage in such ascriptions. A meta-analysis of gender-specific attitudes towards mathematics reveals that boys tend to attribute success to their capabilities whereas girls are inclined to attribute their success to hard work or luck, and claim their failures are the result of lower mathematical aptitude. For girls, these are unfavorable ascriptive patterns that influence their further motivation and can act as a self-fulfilling prophecy.

Our study also presented accounts of scant support and encouragement (Horwath et al., 2007). Whereas the proportion of men and women surveyed who felt that their father had nurtured their interest in technology was about the same (45% versus 51%), 38% of men but only 23% of women said the same about their mother. Women report much less frequently of having had great opportunities to get technical experience, and their retrospective estimation of the contribution made by their school and teachers in fostering their interest in technology is truly alarming: 46% of men but a mere 27% of women claim to have received support and encouragement from teachers, and 14% of women even state that teachers curbed their enthusiasm (versus 3% of men).

The differential perception and treatment of women not only plays a role in upbringing and education; it continues on in occupational life. Discrimination against women in hiring decisions is often the result of unthinking, cliché-based modes of perception and behavior. A good illustration of this is the study by Norton et al. (2004, Study 1). The subjects were assigned the task of selecting, from among five persons, the most qualified for a construction engineering job (whereby the individual should possess a good educational background and work experience). Of the five applicants, two were shortlisted: Person A had better training (certificate in addition to a college degree) and had 5+

years of career experience, whereas Person B had only a college degree (no additional certificate), but 9 years of career experience. In the control group, the candidates were identified only as Person A and Person B, and 76% of the participants in this group selected Person A as the more qualified applicant. To the members of a second group, Person A was presented as a male and Person B as a female, and here as well 75% of the participants assessed Person A as better qualified for the job. Finally, in a third group, Person A was presented as female and Person B as male, the upshot of which was that only 43% of the participants now felt that Person A was the right one for the job. The results of this study show how stereotypes influence thinking. Men conform to preconceptions of what a good engineer is like better than women do, regardless of how much education or experience they have.

Discrimination is often based on relatively small effects, which raises the question of whether a little bit of discrimination can also be relevant. This question was investigated by Martell et al. (1996) with the help of a computer simulation. The authors simulated an organization with an eight-level hierarchy (500 persons on the lowest tier; 10 at the top) and the same number of men and women on each level. Then, a slight promotion bias in favor of men was introduced, and two simulations compared the effects of small degrees of preference/discrimination (5% versus 1% variance in the promotions). Following 20 rounds and as the outcome of minimal discrimination against women, the top level of the institution was staffed by 71% and 65% men respectively. This means that even slight bias can engender significant inequality over time.

The findings sketched above make it clear that stereotypes develop a certain momentum and can become self-fulfilling prophecies. Nevertheless, the question of whether the divergent representation of men and women in science and technology can also – or even primarily – be explained by divergent cognitive skills cannot be answered in terms of the above-described ways that stereotypes are operational in everyday life. Thus, we now turn to the question of whether gender differences with respect to cognitive skills can be identified. What generalizations are permissible according to the latest research?

ARE THERE COGNITIVE DIFFERENCES BETWEEN MEN AND WOMEN?

Relevant criteria for an assessment of the findings yielded by studies of cognitive skills are the questions of which skills are being measured, how are they

measured, and when (at what stage of the lifecycle) are they measured. The results of these studies are complex and sometimes ambiguous, which is why meta-analyses in this area are enlightening. These meta-analyses scrutinize how pronounced a difference is (mostly measured by the effect size d ; Cohen, 1988³) over a number of different studies. The effect size is computed according to statistical formulas; however, this does not indicate when a difference is substantial enough in everyday life to be relevant. That, in turn, is a matter of interpretation and the subject of a controversial debate (for an overview see Ceci and Williams, 2007; Ceci et al., 2009; and Halpern et al., 2007).

First of all, meta-analyses permit the generalization that the cognitive profiles of men and women are largely similar but differ in some areas (Hyde, 2005). In detail, results show that, with respect to general intelligence, no gender differences can be established – i.e. women and men are equally intelligent on average (Halpern et al., 2007). Whereas there are no differences in the mid-range of the performance spectrum, there are differences at both extremes (Hedges and Nowell, 1995). Males display more heterogeneity – i.e. there are more men than women among both the lowest performers and the highest performers. The reasons for this are unclear (Halpern et al., 2007; Lubinski and Benbow, 2007).

Furthermore, meta-analyses indicate differences in the average skill profiles of men and women for certain types of cognitive abilities, whereby these differences vary with the subjects' age. We will now take a closer look at three such areas that can be considered particularly relevant for technical careers: verbal and mathematical capabilities and spatial thinking. Verbal skills are significant because superior performance in technical fields calls for the ability to communicate effectively and to understand abstract ideas. It is important to be able to communicate clearly, understand complex texts, and work together with other people. Verbal skills are an advantage in all academic areas. A perusal of the literature on this subject shows that numerous studies indicate a small to medium gender difference in favor of women (Halpern et al., 2007). Some but not all verbal tests reveal that women have a slight advantage here (see the meta-analyses by Hyde and Linn, 1988; and by Hedges and Nowell, 1995).

3 | The effect size d can range from -3 to +3, with a value of 0 indicating that there is no difference. A value of 0.8 is considered a large, 0.5 is a medium, 0.2 is a small, and <0.2 is a negligible difference (Cohen, 1988). By convention, negative values are used for higher values for women and positive values for higher values for men.

With respect to mathematical skills, the results are less clear. In this area, the one in which gender stereotypes are most highly defined, empirical findings reveal the smallest and the least stable differences in capabilities (Halpern et al., 2007). Thus, an analysis of 100 studies of mathematical skills involving more than 3 million participants indicated no gender difference ($d = -0.05$) for samples of the general population; men performed better in 51% of the studies, 6% found no difference, and women outperformed men in 43% of the studies (Hyde et al., 1990). In other words, it is not hard to find one or more studies that support one's view. In contrast to what the stereotype suggests, there is little evidence that boys are generally more gifted mathematically. Hyde et al. (2008), for example, analyzed standardized testing data of more than 7 million pupils across all grade levels in 10 U.S. states. Of the 66 reported effect sizes (10 states; 11 grades), 21 indicate better performance by boys, 36 indicate better performance by girls, and 9 indicate no gender differences. All effect sizes are smaller than 0.10, which means that the differences can be considered negligible. While the available meta-analyses all indicate that the effect sizes for gender differences in math achievement generally are negligible or very small, they also show that gender differences increase with age (favoring males), particularly at the top performance level (Else-Quest et al., 2010; Hedges and Nowell, 1995; Hyde et al., 2008; Hyde and Mertz, 2009; see also Hyde, 2005).

The last cognitive area we want to consider is spatial abilities. This is a key skill for a wide range of occupations, including architects, surgeons, artists, taxi drivers, and engineers. Many occupations call for the ability to visualize objects from different perspectives, such as for example, while in motion. There are comparatively large and consistent gender differences with respect to this ability, particularly for mental rotation tasks. Again, gender differences in the performance of mental rotation tasks are more apparent among adults than among children. Even if the effect sizes vary considerably across different spatial tasks, men consistently outperform women (see, for example, the meta-analyses by Linn and Petersen, 1985; and Voyer et al., 1995; see also Hyde, 2005).

On the basis of reported research on gender-specific cognitive differences, the following interim conclusions can be drawn. There are no average differences between the sexes with respect to general intelligence, although numerous studies indicate that there are small average differences in the cognitive profile of men and women as measured by standardized tests. The pattern of gender differences is more nuanced than is often assumed. Performance by men seems to be more dispersed than that of women. Gender differences mani-

fest themselves above all in performing verbal tasks (higher average values by women) and spatial tasks (higher average values by men). They often emerge only at a certain age and/or manifest themselves differently in different age groups. As a rule, performance differences can be identified only beginning at adolescence, especially among the highest performers. The differences vary depending on the particular area being considered. The biggest lead by boys emerges at about age 15 in certain spatial tasks (Halpern et al., 2007). Attributing superior mathematical skills to men is hardly tenable. Attributing verbal skills to women and math skills to men is likewise erroneous since both sexes exhibit strengths and weaknesses in particular sub-tests. In most areas, when differences between the genders can even be registered, they are small (Hyde, 2005). The meaning and practical relevance of such differences is less clear.

A pertinent question, of course, is whether the greater heterogeneity on the part of men (at the top and bottom of the performance spectrum) leads to their more frequent professional involvement with science and technology. Since, by definition, only a very small proportion of the population are top performers, there must also be many men employed in technical fields who are not in the top 1% of the performance spectrum. And in the top 5–10%, gender differences are already minimal. It is also important to note that women engaged in technical occupations are underrepresented at all performance levels and not only in the top 1% (Halpern, 2007). Also of interest in this connection is a study by Benbow et al. (2000) that investigated which professions were chosen by men and women who, at age 12, had been classified as highly gifted (top 1% of their cohort). Only a relatively small proportion of the boys were working in a scientific or technical field at age 33, and the proportion of gifted girls was even smaller. It should also be mentioned that, for gender differences in the highest performance group, ethnic differences were identified. In the group of U.S. pupils of Asian descent, for example, there are no gender differences in the highest performance group with respect to mathematical tasks (Hyde et al., 2008).

CULTURAL AND SOCIAL INFLUENCES ON DIFFERENCES IN COGNITIVE PERFORMANCE

Performance differences between boys and girls are also culturally dependent, since tendencies are not identical in all countries. The 2009 PISA Study that tested the performance of 15-16-year-old pupils provides a few indications

here. In the area of reading skills, girls performed significantly better than boys in all OECD countries, where, on average, girls lead by 39 points, which corresponds to more than half a competence level/school year (Schwandtner and Schreiner, 2010; OECD, 2010). In Austria, girls outperformed boys by 41 points, in Germany by 40, and in Switzerland by 39; girls had significantly less of a lead in the Netherlands (24), the U.S. and Great Britain (25), whereas they were far ahead in Bulgaria (61), Lithuania (51), and Finland (55). This means that girls' reading skills as measured by the PISA Study were superior in every case, but the extent to which they outperformed boys varied considerably from country to country.⁴ Furthermore, socioeconomic status had a greater influence on reading skills than gender – i.e. the score difference between the top and bottom quartiles of the pupils' socioeconomic distribution. Among OECD countries, Hungary (118) displayed the greatest difference, and Iceland (62) the least. The OECD average was 89 points, with Austria (102), Germany (105), and Switzerland (94) coming in above average (OECD, 2010).

With respect to mathematical skills, gender differences are less pronounced. In the OECD, boys average 11 points higher than girls.⁵ In 35 of the 65 participating countries, boys outperformed girls. In Austria and Switzerland, the boys' lead was 20, in Germany 15 points. Among Austrian pupils surveyed, the boys' average score (506) topped that of girls (486); nevertheless, in such countries as Korea (544), Finland (539), and Switzerland (524), girls finished first (Frey et al., 2010).

These elaborations show that both the extent and the direction of gender differences vary from country to country and across ethnic groups, a finding also highlighted by recent meta-analyses (Else-Quest et al., 2010; Hyde and Mertz, 2009). Moreover, the influence of the respective school system and the extent to which it provides equal opportunity education can amplify or diminish performance differences. Equal opportunity manifests itself in endeavors to minimize competence differences between socially privileged and disadvantaged youths. In all participating countries, social background influenced pupils' achievements, though the strength of the interrelationship between socioeconomic status and competence differs among the individual countries. In Finland, for instance, pupils' achievement hardly correlated with their family's socioeconomic status; in Austria, it did to a considerable greater extent,

4 | The range is 22-55 difference points in the OECD member states, and 9-62 difference points in the partner countries.

5 | OECD mean, girls: $M=490$, $SD=0.6$; boys: $M=501$, $SD=0.6$ (Frey et al., 2010).

whereby this applies especially to those whose immediate family migrated to Austria (Schwandtner and Schreiner, 2010).

Gender-specific performance differences are neither immutable nor indispenible, and the differences between the genders are often less than the differences between the countries. The factors underlying national differences are multifaceted. Naturally, a country's economic strength and the quality of its educational system are key variables. The degree of gender stratification in a society also seems to play a role. Baker and Jones (1993) analyzed the international pattern of gender differences in mathematics achievement and discovered that there is a correlation with the proportion of women in the workforce ($r = -.55$). In other words, the more women are engaged in gainful employment, the less there are gender differences in mathematics achievement. An interrelationship between gender differences as established by PISA 2003 and four indicators of the social role of women in various countries was also reported by Guiso et al. (2008). The analysis reveals a tendency whereby gender differences in mathematics are considerably smaller – or even vanish altogether – in those societies that display a high degree of gender equality (see also Else-Quest et al., 2010; Hyde and Mertz, 2009). For spatial abilities, a study by Hoffman et al. (2011) showed for two tribes of comparable genetic background in Northeast India that the gender gap disappeared when moving from a patrilineal society to a matrilineal society.

In addition to international differences, those within a particular society are relevant too. In a study of children from economically less-well-off families, Levine et al. (2005) found no gender differences in tasks involving spatial thinking, whereas there were marked differences among children of middle- and high-income families. These findings can be viewed as an indication that training cognitive skills – just like development of spatial thinking by boys – depends on the experiential opportunities made available to a child (e.g. computer games, jigsaw puzzles, sets of building blocks, etc.).

Finally, it should be mentioned that gender differences in cognitive skills have also changed considerably over time. The differences established by numerous – though not all – tests have diminished (see the review by Hyde, 2005 that considered 46 meta-analyses). The difference between women and men in the top performance sector has also decreased (Halpern et al., 2007; Wai et al., 2010). The proportion of female college graduates has risen sharply, and the probability that a woman will graduate college is significantly higher today than it was 30 years ago. The graduation percentage of women is greater or equal to that of men in 21 of 27 OECD countries (OECD, 2004).

ON THE INTERPRETATION OF COGNITIVE GENDER DIFFERENCES

As already implied in previous sections, the interpretation of the results plays a decisive role in discussions of cognitive skills. For example, schoolchildren in the U.S. have been doing poorly in comparison to their peers abroad in tests on scientific-technical subjects for years now, but this hardly leads to the presumption that Americans have less of a chance to succeed in science (Hines, 2007). The question of whether the low proportion of women in science and technology can be explained by gender-specific differences in cognitive skills essentially asks whether women are less talented or less suited to technical occupations than men. It attributes certain cognitive deficits to women, even if it does so indirectly and sometimes even in a benevolent manner. The question is additionally problematic in that it proceeds under the implicit assumption that a single talent or ability makes for success, that standardized tests can measure this talent or ability, and, furthermore, that talent and ability are stable and thus unalterable (Valian, 2007). But the paths from skills to careers are subject to numerous factors. Even if certain abilities seem to be required for success in technology and science, there is often no objective standard of how much of a skill is necessary for students to become good technicians or scientists.

It seems even more characteristic that, in discussions of cognitive differences, this matter is often reduced to the question of whether this is biologically determined or due to socialization (social class phenomenon, attributable to the influence of parents and peers, or a consequence of how much effort went into nurturing interest in science and technology). This frequently observed (implicit) act of equating inborn/acquired with immutable/mutable nevertheless proves to be essentially problematic since biology is not necessarily an eternal fate. Otherwise, many health initiatives would be in vain – think of surgical interventions or lifestyle modifications such as a better diet and exercise to lower the risk of heart disease or diabetes. In many other spheres of life, biologically-caused conditions most certainly are considered alterable, and no attention is paid to differences in people's biological makeup (grey hair can be dyed, illnesses medicated, etc.). And, after all, the educational system would be obsolete if it were predetermined at birth who would later develop which abilities and be suitable for which occupation. In the cognitive area as well, people in modern societies use medicine, technology, and training all the time to influence their abilities.

The lifelong process of developing cognitive skills is carried out in an environment in which biological, social, and cultural influences constantly interact and reciprocally affect each other. Capabilities are nurtured by means of learning processes that likewise display biological, social, and cultural facets (Halpern et al., 2007; Halpern, 2004). Accordingly, people have to be considered biological and social beings in equal measure. It should also be kept in mind that there are maturation processes – for example, if differences emerge only at a certain age, this can mean that a differentiation is biologically determined to occur in a particular phase of life, or it might mean that the difference takes place at this time due to socialization. Therefore, so-called inborn gifts can only mean a potential more or less available, a predisposition that, in a setting that fosters its development, is highly cultivated or not.

The interplay of biological and social influences also manifests itself in reciprocal interaction of brain structures and experience. It is not only so that biology influences behavior; human action can also have an impact on biology. Studies of London taxi drivers by Maguire et al. (1997, 2000) created quite a stir in this connection. In comparison to a group of adults whose occupations did not call for spatial skills, the cabbies exhibited an enlargement of the right front area of the hippocampus. Furthermore, there were indications of a correlation between the number of years of taxi-driving experience and the size of that part of the brain. In another study, Draganski et al. (2004) found that practicing juggling for three months produced a thickening of the grey substance in the lateral prefrontal cortex, the region of the brain presumed to control such movements. Here as well, scholars proceed on the basis of a direct connection between behavior and brain morphology. Studies of piano players show that those who were already intensively practicing ambidextrously prior to age 6 displayed more symmetrical handedness as adults, as well as a thicker corpus callosum than musicians not trained to be ambidextrous (Jäncke et al., 1997; see Schlaug et al., 1995). These studies show that biological differences can also result from different experiences (also see Jordan-Young in this volume).

In the 19th century, American scientists believed women and Black men to be less intelligent because they have smaller brains, and German scholars felt superior to their French colleagues on the basis of the same assumption (Gould, 1981). Scientists no longer pay much attention to brain size; they attribute greater importance to how the various regions of the brain function, but here too the interrelationship with cognitive skills remains unclear (Halpern et al., 2007). For example, research is being done on whether the same areas of the brain are activated when men and women perform identical tasks (for an

overview, see Haier, 2007). These researchers have found that when men take a mathematics test, the greater the activation of the temporal lobe, the higher the test score. As for female test takers, there was no connection between activation of a region of the brain and the score achieved (Haier and Benbow, 1995). These results are interesting because they show that women and men can perform comparable cognitive tasks by using different areas of the brain. Findings of research on the function of brain regions also shows a relationship with an individual's previous experiences – for instance, among speakers of a second language, a different area of the brain is activated depending on whether the second language was learned before or after four years of age (see Wattendorf et al., 2001).

A currently very widespread hypothesis on biologically determined gender differences has to do with sex hormones, but here as well in the area of cognitive skills we have to proceed on the basis of complex reciprocities. In the brain, there are gender differences that are induced by hormones, but the brain's development is simultaneously influenced by experiences. Hormones undoubtedly influence behavior, but at the same time hormonal secretion varies depending on environmental influences (Halpern et al., 2007). Performance differences seem to correlate with fluctuations in hormone balance, but these fluctuations can be triggered by such influences as stress, weather, diet, and psychological burdens.

Thus, the common simplification that equates biological with unalterable and social with subject to modification is untenable. Social experiences and circumstances influence biology just as, conversely, biological influences play their roles in conjunction with modes of social behavior and cognition. As interesting as these results might be with respect to the question of whether differences in cognitive skills can explain women's lesser degree of representation in science and technology, this nature-versus-nurture discussion does not get us very far. Accordingly, we now turn to the question of whether existing cognitive skills can be influenced and changed, and if so, how.

CAN COGNITIVE SKILLS BE INFLUENCED?

The question of whether cognitive skills can be influenced brings out divergent preconceptions since it implies that capability can be understood as both a stable characteristic as well as one that can be influenced over the short or long term. This differentiation is revealing from a theoretical point of view and is also im-

portant for designing measures to ensure fairness with respect to gender. In the following section, we will first look into whether situative determinants (such as updating stereotypes) can influence performance by men and women. Then, we will report on research findings as to how preconceptions of what skills can have an impact on cognitive performance. Finally, we will address the question of whether cognitive skills respond to long-term training and, if so, to what extent.

Situative Suggestability and Stereotype Threat

Female student 1: Does he tell jokes that demean women during the lecture?

Female student 2: Yes!

Female student 3: Before an examination.

Female student 4: Yes.

Female student 3: If he only wants to start at quarter after and not at five minutes after, he says: "I'll tell you a quick joke ..."

This exchange took place during a group discussion in conjunction with our study. The female students are obviously trying to come to terms with experiences they have had as women. A misogynistic joke is not usually regarded as seriously offensive but it is nevertheless disconcerting for these female students. What are we to make of an instructor like the one mentioned above who, right before a test, tells a joke that demeans women? Can this experience influence the performance of those who were the butt of the joke?

Insights into this issue are provided by numerous studies conducted in connection with the so-called stereotype threat approach (for an overview, see Inzlicht and Schmader, 2012). The phenomenon of stereotype threat was described in order to explain performance differences between men and women as well as between White and Black students. The first published study had to do with performance differences between Whites and Blacks in the U.S. (C.M. Steele and Aronson, 1995). Study participants who are Black and, prior to being administered a test, were asked to specify whether they are Black or White, got significantly lower scores than Black participants whose attention was not directed to their skin color before taking the test. Stereotype threat thus refers to the experience of threat that a person's performance might be interpreted in light of his/her membership in a negatively stereotyped group. Negative performance expectations with respect to one's own group can lead

to situative stress, which is detrimental to performance. The mere awareness of the existence of stereotypes can lead to a performance decline, so it is not even necessary to put credence in the stereotype. In other words, when an individual is tested in an area associated with a negative stereotype about the test taker's own group, then a subconscious "threat in the air" (C.M. Steele, 1997) can be operational and, like a self-fulfilling prophecy, lead to poorer performance.

Since the inception of this concept, there have been many studies on stereotype threat in the context of women and mathematics/technology (e.g. Dardenne et al., 2007; Good et al., 2008; Inzlicht and Ben-Zeev, 2000; Quinn and Spencer, 2001; Spencer et al., 1999; see Nguyen and Ryan, 2008 for a meta-analysis). Typically, a test is administered to male and female students, controlling for prior capabilities. One group is told in advance that in the past, the test results revealed gender differences (whereby men scored higher than women) and a second group is told that no gender differences are expected. And indeed, in the first group, women did score lower than men, whereas no performance differences were observable under the second set of circumstances (Spencer et al., 1999). It is interesting to note that it is not even necessary to directly point out the expected gender differences to the test takers, as in the above-mentioned study, in order to achieve this effect. Subtle and situative allusions such as the proportion of men and women in the group taking the test can also trigger the effect (i.e. women in the minority have a higher risk of suffering diminished performance than women in a group that is balanced with respect to gender) (Inzlicht and Ben-Zeev, 2000).⁶ If a stereotype is sufficiently well-known, then it evidently suffices to merely remind the test takers – explicitly or implicitly – of the fact that they belong to this group. Many women are well aware of the stereotype that women are less gifted than men in mathematics, so that this can result in a real diminishment of their performance.

Stereotype threat represents situative performance pressure whereby women are made to feel that they have to refute the stereotype that they are less mathematically or technically inclined than men. But it is precisely this high-

6 | In such cases, individuals are often not even aware that the stereotype is having a deleterious effect on them. Blascovich et al. (2001) administered a test to Blacks and Whites, and confronted test takers with the stereotype that Blacks' test results were expected to be lower. Blacks reported that, in the stereotype threat condition, they did not feel more anxious or impaired due to the stereotype; nevertheless, their blood pressure was significantly higher, which can be interpreted as an indication of tension attributable to the stereotype.

pressure situation that actually does impair their performance. Ironically, the strongest stereotype threat effects manifest themselves on the part of individuals who are particularly gifted and highly interested in the respective subject matter (Aronson et al., 1999) – i.e. in the present context, vulnerability to such stereotyping is greatest among women who strongly identify with mathematical and technical content. The effect is also stronger among those who identify with their own group (Schmader, 2002) – i.e. women for whom being female is an important part of their identity. These people are particularly concerned with disproving negative expectations. Furthermore, the effect has the strongest repercussions when the individual faces a daunting task. If the assignment is easily completed, then the motivation to refute the stereotype does not hinder coming through with flying colors; in fact, putting in a bit more effort – summoned forth by the desire to lay a stereotype to rest – can even lead to performance enhancement (O’Brien and Crandall, 2003).

It is important to emphasize that stereotype threat is defined as a cognitive mechanism that does not spare White men either. For example, Aronson et al. (1999) conducted a study in the U.S. that confronted White men with a stereotype that is very widespread in that country – that Asians are more gifted in mathematics than other American ethnic groups. In comparison to the control group that was not confronted with this stereotype, White men that were confronted with it actually did suffer a significant decline in performance on a mathematics test. In such situations, men as well are susceptible to stereotype threat effects due to social stereotypes that predict inferior performance – in the realm of emotional sensitivity, for instance (Leyens et al., 2000).

This research approach thus shows that performance differences in tests can be caused not only by cognitive differences but also by situative factors. Nevertheless, it must also be pointed out that cognitive differences between men and women are not attributable solely to the impact of stereotypes (Sackett et al., 2004). Rather, the results of studies on the subject of stereotype threat show that the activation of stereotypes can overlay and further enlarge existing differences. Important in this context is that stereotypes constitute significant sources of stress for members of stereotyped groups, and can cause real diminishment of performance.

Concepts of the Changeability of Intelligence

If stereotypes actually can lead to performance impairment, then what can be done to prevent this? A casual remark that a test is gender-neutral and not

designed to detect gender differences might be all it takes to provide relief to those troubled by stereotype-related fears (Spencer et al., 1999; Quinn and Spencer, 2001). But stereotypes are operational not only in test settings but also in learning situations in which individuals are confronted with new material (Appel and Kronberger, 2012; Appel et al., 2011) – for example, at the beginning of undergraduate study.

Such situations can often be distressing since, when people begin an effort to learn something new, initial failure to comprehend it is less the exception than the rule. Indeed, the significance of this essentially normal situation should not be underestimated. The participants in our study (Horwath et al., 2007) discussed this problem of their initial inability to understand course material and the accompanying feeling of self-doubt.

Long-term studies (summarized in Dweck, 2007) suggest that women have particular difficulty dealing with such perplexity – in fact, the brighter they are, the harder it is. Intelligent boys, on the other hand, are often spurred on by failure to understand. Thus, this is actually a matter of how students deal with experiences that cast doubt on their abilities. Of key importance here are concepts of what an individual's capability actually is: an inborn endowment or an acquired skill? If one considers one's capability as a gift, then a setback can quickly lead to a loss of motivation to stick to it (since the failure is interpreted as a lack of talent). If, on the other hand, one is convinced that achievement can result from hard work and determination, then there is a higher probability one will display resilience in upsetting situations.

Grant and Dweck (2003) surveyed freshman studying chemistry at Columbia University. Women who interpreted their ability as a talent did comparatively worse; they considered their abilities as given and unchangeable. On the other hand, the performance of women who were convinced that practice makes perfect was as good as that of their male classmates. These results illustrate the fact that all women are not equally at risk of getting discouraged by disturbing situations. Their vulnerability rather depends on convictions (that can be inculcated) (Dweck, 2007).

What makes the capability-as-inborn-gift mentality so dangerous is its inherent implication that we can ascertain in advance who is talented and who is not (according to the stereotype regarding technical fields: men have the right stuff; women have less of what it takes). Accordingly, women who consider their own high performance as a gift are susceptible to setbacks. Bad grades, for instance, can easily lead to frustration. If, on the other hand, the message is

conveyed to students that hard work leads to success, then this has an encouraging effect on both genders.⁷

Now, teachers who wish to encourage women could wait for situations in which a woman does a great job and then praise her for her talent, but, paradoxically, this is precisely the problem. A series of investigations by Mueller and Dweck (1998), for example, show that praising students' talents (even in response to a performance that actually was outstanding) can have undesirable side-effects. It can induce students to hesitate to embark on tasks in which there is an intrinsic risk of failure. So what can be done? Dweck and her colleagues proceed under the assumption that the point is to influence convictions about what talent actually consists of (also see Aronson et al., 2002). Over the long term, imparting the idea that intelligence is subject to modification and development yields the highest probability of having a heartening effect. In concrete terms, teachers should instill the conviction that capabilities can be upgraded through indefatigable effort. Thus, via an encouraging, supportive attitude, they can help women and men learn to overcome frustration and not to give up prematurely when a situation induces self-doubt.

Long-term Influence on and Training of Cognitive Skills

Calling upon educators to teach that capabilities are assets subject to enhancement raises the legitimate question of the extent to which capabilities actually can be modified. By way of example, we want to focus on the above-mentioned area in which the most pronounced gender differences have been established – spatial abilities. Marulis et al. (2007) presented a meta-analysis of the trainability of this skill; they come to the conclusion that both children and adults can train and improve this skill by engaging in a series of activities such as task-related practice, musical exercises, and computer gaming. A meta-analysis by Baenninger and Newcombe (1989; cf. Newcombe, 2007) also found that spatial abilities can be trained, and that both men and women

7 | Consider as well the open letter that Harvard University physicist Howard Georgi published in the school newspaper in January 2005 in response to remarks made by President Larry Summers. Implicitly, Georgi also made it clear that achievements in physics are not to be understood only as the result of innate talent but of continuous hard work too (Available at: <http://www.thecrimson.com/article.aspx?ref=505377> (accessed 12 February 2013)).

benefit from such training. Repeated training sessions constitute the key to enhanced performance (e.g. Cherney, 2008). Sorby and Baartmans (2000) set up a course for freshmen at Michigan Technological University in which spatial conceptual abilities were trained. The evaluation showed a significant improvement in performance by men and women, and even lowered the drop-out rate. Gerson et al. (2001) used multimedia software to train freshmen's spatial abilities, resulting in a reduced drop-out rate among female engineering students.

On the whole, the literature on training mental skills shows that abilities certainly can be developed, and some studies suggest that gender differences can be reduced (e.g. Feng et al., 2007; Spence et al., 2009; Tzuriel and Egozi, 2010). In a critical analysis of the training literature, however, Ceci and Papierno (2005; see Voyer, 1995) point out that training need not necessarily erase gender differences. Sometimes those with better skills also benefit more from training, increasing rather than weakening existing gender differences. Overall it seems that women largely benefit from training, even if they do not necessarily benefit more than men. More important than the question of whether or not women can 'catch up' seems to be the insight that abilities can be successfully developed. The training studies show that the average improvement in performance is often greater than the gender differences and if a certain performance standard is set, both sexes can be trained to meet it.

CONCLUSION

Important for the issue under investigation here is recognizing that cognitive skills can be influenced both negatively and positively. A comprehensive review of research shows that we have a lot to learn about the influence of stereotypes on individual performance, that prevailing assumptions about the nature of intelligence and talent ought to be subjected to critical scrutiny in child rearing and education, and that relevant skills can be considerably enhanced via practice and perseverance. This leads us to conclude that there are both similarities and differences in the average profiles of men and women with respect to cognitive skills. Furthermore, these capabilities are by no means fixed; rather, they must be seen as constituting developmental potential that can certainly be nurtured. In any case, cognitive differences in the average profiles of men and women can hardly be singled out as the only reasons for the lower proportion of women active in technology and science.

Science and technology education are contexts in which equality and difference between men and women are both discussed, organized, and produced. This is why discussions of gender justice and cognitive abilities are of essential importance here. Our analysis shows that the question of whether there are cognitive differences between women and men is not easy to answer. As we have endeavored to show, fixation on this question can also frequently lead to a dead end since the key would be to know what practical relevance possible differences have in everyday life. As far as educators' ability to intervene, the question of how men's and women's cognitive skills can be influenced seems to us to be especially important. Here, researchers have been very active and produced impressive empirical results that permit concrete insights into the practical implications of moving towards gender justice. This paper has presented and discussed current scholarship on these issues.

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