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Stereotypes in a polarised world and how they relate to mathematical identity

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Previous studies have indicated that men are stereotyped as more mathematical than women. Since these stereotype images have shown psychological effects—particularly for negatively stereotyped groups—it is relevant to ask how variables other than gender relate to mathematics. In this study, we examined how stereotype characteristics of gender, occupation, political views, and personality relate to mathematical identity. From statistical analyses of Comparative Judgement data, we show significant associations between mathematical identity and extreme stereotypes (related to occupation, political views, and personality). No significant association was found between mathematical identity and gender.

Keywords: Stereotypes, mathematical identity, gender, occupation, political views, personality.

Introduction

Men are often stereotyped as more mathematical than women (e.g., Picker & Berry, 2000). Regardless of how accurately such stereotype images reflect reality; they affect people (e.g., Danielsson et al., 2019; Herzig, 2004; Jugović et al., 2012). An experimental study showed, for example, that women underperform relative to equally qualified men when they, incorrectly, are told that mathematics achievement tests are gender-biased. When they are not informed about this made-up gender bias, men and women perform equally (Spencer et al., 1999). Studies like these exemplify that stereotype images in mathematics are both real and significant.

If there exist stereotype images about gender and mathematics, and if these images affect people, then similar phenomena might exist for other variables. We argue, therefore, that stereotype research in mathematics education should examine: (1) how stereotype images other than gender relate to mathematics, and (2) how such images—insofar as they exist—affect people (in particular, how they affect those who are stereotyped negatively).

In the study on which we report in this paper, we addressed the first of these issues. That is, in addition to gender, we examined how people associate mathematics to three variables: occupation (income, education, and practical/theoretical work), political views (regarding the environment, taxes, state regulations, the EU, and immigration), and five facets of personality traits, known as “the Big Five” (Goldberg, 1993). We chose these variables based on a conjecture that they represent a tendency in Europe and elsewhere, namely that, besides gender, people identify themselves (and others) in extreme opposites; people regard themselves and others, not only as males and females, but also as left-wingers and right-wingers, practical and theoretical, extroverts and introverts, and so forth. How such variables relate to mathematics is unclear.

Using a Comparative Judgement (CJ) design (which we describe later), 34 Norwegian university students were first introduced to the term mathematical identity (MI), which we define in the next section. Subsequently, the students were shown multiple pairs of extreme characteristics (e.g., one

person who is against eco-friendly policies; another person who has a high education), and they were asked to judge which of these characteristics that best reflect a person with a strong MI. The results on which we report in this paper answer the following research question: *How do stereotype characteristics of gender, occupation, political views, and personality relate to MI?*

Theoretical framework

Mathematical identity

Similar to Deaux (1993), we view in this paper MI as a relationship between *social MI* and *personal MI* (e.g., Kaspersen et al., 2017). When we refer to social MI, we mean a set of (relatively) agreed-upon characteristics of what it means to be mathematical within a specific context. For example, “making sense of proofs” is a member of social MI, but only insofar (1) most persons within an observed context agree that making sense of proofs is a characteristic of MI and (2) that they interpret in similar ways what proofs are and what it means to make sense of them. Limits for what counts as “most persons” and “in similar ways” depend on the context of the study.

When we refer to personal MI, we mean the extent to which individuals identify with the set of characteristics that constitute social MI within the activity in which they participate. For instance, if a person usually tries to make sense of proofs when she sees one, this characteristic is a part of her personal MI, but only if she participates in an activity where the characteristic is also a member of the social MI.

These definitions are motivated to allow sentences that include measures (e.g., “person A has a stronger MI than person B”). As described in Kaspersen (2018), these sentences are nonsense unless there exists a body of reference, and this is the role of social MI: It is the body of reference to which personal MIs can be measured. When people respond to a MI instrument, a rough interpretation is this: the items (and their psychometric properties) represent the social MI; how person A responds to the items represents person A’s personal MI.

Twenty characteristics of social MI have proven to have relatively robust psychometric properties within (but not necessarily between) a wide range of contexts (Kaspersen, 2018). The characteristics include: “liking to discuss mathematics”, “trying to understand formulas/algorithms”, “struggling with putting mathematics problems aside”, “taking time to understand why some methods in some cases do not work”, and “taking the initiative to learn more mathematics than what is required”. That the characteristics have robust psychometric properties means that they can be applied in instruments (e.g., questionnaires) that measure MI.

In this study, the expression “individuals with low MI” means persons who select the lower categories (e.g., “never”) when they respond to an MI instrument that contains characteristics of social MI. By contrast, “individuals with high MI” means persons who select the higher categories (e.g., “always”) when they respond to the same instrument.

Stereotypes

Stereotypes have been studied for more than a century (e.g., Brauer et al., 2001; Brigham, 1971; Spencer et al., 1999). Nonetheless, researchers disagree on how the term should be defined. In a

review of stereotype definitions, Kanahara (2006) documented that some researchers include truth-values in their definitions. Some define stereotypes as relatively true beliefs; others define them to be mostly false. In this paper, we take Kanahara's (2006) position, namely, that the truth-value of a stereotype is a question of empirical matters: In some cases, stereotypes are relatively accurate; in other cases—for example, when mathematics is portrayed as a male domain—they represent the matters of facts fallaciously.

In his synthesis, Kanahara (2006) claimed that definitions of stereotype share two characteristics: (1) they describe stereotype as related to beliefs (e.g., Allport, 1958); and (2) they describe stereotype as a group concept (Giddens, 2001; Krech et al., 1962). Accordingly, Kanahara (2006) defined stereotype as “a belief of a group of individuals”, and this is the definition we use in this paper. Specifically, we report in this paper on how students compare beliefs about several groups of individuals—males, females, left-winger, right-wingers, etc. —and how these stereotypical images associate with MI.

The four variables used in the study

We have studied how students compare stereotype images of persons with different genders, occupations, political views, and personality traits. Although none of these variables is dichotomous, the students in this study were asked to consider only extreme opposites. For *gender*, the students stereotyped males and females only. For *occupation*, the students stereotyped persons with six characteristics: low income, high income, low degree of education, high degree of education, practical work, and theoretical work. For *political views*, the students stereotyped persons with ten values: positiveness towards environment-friendly policies, low taxes, state regulations, the EU, and immigration, and negativeness towards these issues. For *personality*, the students stereotyped persons with high or low measures of the facets of the Big Five (Goldberg, 1993), that is, persons with high or low measures of conscientiousness, openness, extroversion, agreeable to experiences, and neuroticism. These characteristics and measures of how much the students associated them with MI are represented in Table 1.

Methods

Participants and data collection

The participants of the study were a convenient sample of 34 student teachers at a Norwegian university. In the first phase, each person responded to an instrument for measuring MI (Kaspersen et al., 2017), which contained 19 statements of MI (one item in the original instrument is reversely coded and was removed in this study). When they had finished, the participants were told that the instrument measures MI and that persons who respond in the lower categories have lower MI than persons who respond in the higher categories. Moreover, the participants were told that the purpose of this first phase was only to familiarise them with the concept of MI.

In the second phase, each participant responded to items of a CJ instrument. A detailed description of CJ methodology and how it can be applied in mathematics education was described by Jones and Inglis (2015). Here, we present a rough outline only. Briefly, CJ is based on a psychological principle: humans are poor at estimating measures but good at comparing them. For instance, it is easier for

teachers and other experts to compare the qualities of two mathematical arguments, two mathematical texts, two forms of instructions, and so forth than for them to give measures to each of these things.

The data collection of CJ follows this principle: multiple individuals compare multiple pairs of items, usually using a digital platform. In this study, NoMoreMarking (nomoremarking.com) was used for data collection. For each comparison, the participants were asked: “Which of these persons do you think have the higher MI?” They could then choose between two stereotype descriptions, each holding one of the characteristics listed in Table 1.

For the personality traits, the respondents were not given category labels (e.g., “highly conscientious”), but instead a brief description of those categories (e.g., “a person that is performance-oriented, orderly, self-disciplined, and thorough”). For simplicity, however, we use the category labels when we report the results in this paper.

A sample task is presented in Figure 1. For the respondents, the pairs of items that appeared on the screen seemed to be randomly selected, although they were adaptively chosen by the software to increase the statistical information. Each person made 28 comparisons; thus, the data comprised 952 comparisons in total. To increase the statistical information further, we allowed comparisons of non-opposite characteristics (as the case in Figure 1 illustrates).

Which of these persons do you think have the higher mathematical identity?	
A person who is against eco-friendly policies	A person with high education

Figure 1: Sample task

Analyses of CJ data is, in principle, similar to Rasch analysis: A maximum likelihood estimation is conducted to estimate the most likely measures of each item (in this study: stereotype characteristics) given the observed data. Subsequently, analyses are conducted to assess dimensionality, judge agreement (i.e., the extent to which the results depend on individual judges), and reliability.

Regarding dimensionality, a crucial question is this: does it make sense to compare the items in the instrument? For instance, does it make sense to make the comparison in Figure 1? In the CJ paradigm, an answer is this: If the judges (here: the students) respond in ways predicted by the Rasch model, the items are sufficiently unidimensional; by contrast, if the judges respond unpredictably, the items are too multidimensional for comparisons to make sense. Infit Mnsq—an information-weighted squared difference between modelled and empirical data—is one indicator of uni-dimensionality. Roughly, when the Infit Mnsq of one item is substantially greater than 1 (in this study, we used 1.3 as a threshold), it indicates that this item is so different from the other items (i.e., it belongs to a different dimension) that it does not make sense to include it in the comparisons.

Regarding judge agreement, a crucial question is whether different judges make different comparisons for similar pairs of items. For instance, will different judges make different judgements on the task in Figure 1? In the CJ paradigm, each judge is associated with an Infit Mnsq value. The interpretation of judge Infit Mnsq is about the same as for item Infit Mnsq: If a judge Infit Mnsq is

substantially greater than 1 (in this study, we used 1.3 as a threshold), it indicates that the judge makes judgements that differ substantially from the rest of the judges.

Overall, the analyses showed good psychometric qualities. The reliability was .91, and the largest item Infit Mnsq was 1.3 (“a person who has a theoretical work”). Two persons had Infit Mnsq greater than 1.3 (1.4 and 1.5 respectively), which means that they in some cases made unpredictable answers relative to the rest of the group. However, removing these persons from the analyses had no statistical implication. Thus, the results on which we report in the next section represent a shared agreement amongst the students who participated in the study.

When measures for the items had been estimated, we conducted classical *t*-tests for each pair of contrasting items using a Bonferroni adjusted alpha level of 0.004. For instance, a *t*-test was conducted to assess whether the students associated individuals with high income and those with low income differently to MI. To more directly compare the null hypothesis with the alternative, Bayesian *t*-tests were conducted. Under the null hypothesis, we expected an effect size of 0, and the alternative hypothesis was two-sided. Before observing the data, we assumed that δ followed a Cauchy distribution with scale $r = \frac{1}{\sqrt{2}}$. All analyses were conducted in R (R Core Team) and JASP (JASP Team, 2020), and all measures are reported in logit units.

Results

Gender

In contrast to previous studies, the results in this study indicated no significant differences ($p = .583$) in how students related gender to MI. The Bayes factor was $BF_{01} = 4.7$, which means that the observed data was almost five times as likely under the null hypothesis (i.e., that males and females are associated equally with MI) than under the alternative (i.e., that males and females are associated differently with MI).

Occupation

Three characteristics of occupation—income, education, and work—showed significant ($p < .001$) associations with MI. In effect, the students stereotyped persons with low income, low education, and practical work as having lower MI than persons with high income, high education, and theoretical work, who were stereotyped as having higher MI. In all cases, the Bayes factors ($BF_{10} = 6.9e + 10$ being the least) showed decisive evidence for the alternative hypothesis, namely that occupation characteristics associate differently with MI.

Political preferences

Associations between MI and five contrasting political preferences were assessed. The overall image is that students stereotyped persons positive towards immigration and environment-friendly policies as having a higher MI than persons hostile towards these issues ($BF_{10} = 18.1$ and $BF_{10} = 6760.2$ respectively). There was no significant difference between left-wing and right-wing values for the remaining political issues: attitudes towards taxes, state regulations, and the EU.

Personality

There were also significant differences in how the students connected personality traits and MI. Roughly, the students stereotyped conscientiousness persons as having a higher MI; persons with high measures on the remaining personality traits—extraversion, agreeableness, openness to experiences, and neuroticism—were stereotyped as having a lower MI. The most significant differences were found in conscientiousness and neuroticism. That is, persons that are laid-back, messy, and careless (low conscientiousness) were stereotyped as having a lower MI as compared to individuals that are performance-oriented, orderly, self-disciplined, and thorough (high conscientiousness). Moreover, persons that are sensitive, worried, cheerless, and have mood-changes (high neuroticism) were stereotyped as having a lower MI as compared to individuals that are emotionally robust, handling stress, and balanced (low neuroticism).

Table 1: Characteristics of stereotyped MI

	Stereotyped as lower MI	Measure	Stereotyped as higher MI	Measure	<i>p</i>
Gender					
	Male	0.23	Female	0.44	.583
Occupation					
	Low income	−2.43	High income	1.31	< .001
	Low education	−3.26	High education	4.09	< .001
	Practical work	0.14	Theoretical work	4.02	< .001
Political views					
	Non-environmental	−1.03	Environmental	0.22	.002
	Against low taxes	−0.49	Pro high taxes	0.22	.069
	Against state regul.	−0.91	Pro state regul.	−0.23	.077
	Against EU	−1.06	Pro EU	−0.81	.506
	Against immigration	−2.51	Pro immigration	−0.51	< .001
Personality					
	Conscientiousness (low)	−2.47	Conscientiousness (high)	4.28	< .001
	Openness (high)	−0.91	Openness (low)	1.88	< .001
	Extroversion (high)	−0.60	Extroversion (low)	1.42	< .001
	Agreeable to exp. (high)	−1.58	Agreeable to exp. (low)	−0.30	.001
	Neuroticism (high)	−1.28	Neuroticism (low)	2.18	< .001

Discussion

We have maintained that research in mathematics education should examine: (1) how stereotype images other than gender relate to mathematics, and (2) how such images affect people (in particular, how they affect those who are stereotyped negatively). In this study, we considered the first of these issues, and we have shown that there are significant associations between extreme stereotypes (related to occupation, political views, and personality) and MI. No significant association was found between gender and MI.

It is worth noting that the format of the questions in the instrument in this study has some consequences. That is, the respondents in the study were asked: «compare X with Y; which one do you believe have the strongest MI?» They were not asked: «imagine a person with a strong MI; is the person an X or a Y?» Accordingly, it is crucial to make clear which inferences we can draw from the results presented in this paper. We conclude on the form «X are stereotyped as having higher MI than Y»; not on the form «persons with strong mathematical identities are stereotyped as X».

Having made this distinction, we maintain that the significance of the results presented in this paper depend on answers to the second issue, namely, how stereotype images of MI affect people. This is an issue on which we have no data. Nonetheless, we propose a working hypothesis for future research: stereotype images of MI cause similar effects as they do in nearby domains, namely, a stereotype-threat (ST) (Spencer et al., 1999) for people who are stereotyped negatively and a stereotype-lift (SL) (Walton & Cohen, 2003) for those stereotyped positively. In effect, ST and SL function as a self-fulfilling prophecy: If people belong to a group that is stereotyped as having a low MI, they will develop it as such, and vice versa.

We emphasise that SL and ST do not depend on stereotype images to be true (e.g., Spencer et al., 1999). Nevertheless, it is relevant to ask whether the stereotype images presented in this study reflect reality accurately. Suppose that persons with certain occupations, political views, and personality traits have stronger MIs than others. In that case, we might ask ourselves: how do we establish an educational system so that everyone can participate equally (and agree upon the standards) in complex questions that require scientific evidence: questions regarding equality, immigration, vaccination, and global warming? Alternatively, if the students in this study were inaccurate in their descriptions, we might wonder why some groups in society are falsely portrayed as having a lower MI than others and what the practical implications of these images are.

Although we have no empirical answers to these issues, we maintain that future research on stereotypes and mathematical identity should confront the most urgent issues in what seems to be an increasingly polarised society.

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