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Ricarda Steinmayr & Birgit Spinath

Intelligence as a potential moderator in the internal/external frame of reference model

An exploratory analysis

Abstract

According to the internal/external frame of reference model (I/E model; Marsh, 1986), achievement influences the ability self-concept via internal (dimensional) and external (social) comparison processes. Person characteristics have rarely been investigated with regard to their potential moderating influence on the processes postulated in the I/E model. The present study investigated intelligence as a potential moderator in the I/E model. Grades in German and math as well as the corresponding domain-specific ability self-concepts (SESSKO; Schöne, Dickhäuser, Spinath, & Stiensmeier-Pelster, 2002) were assessed in a sample of $N = 342$ 11th and 12th graders with a mean age of $M = 16.94$ ($SD = .71$). The processes proposed by the I/E model were replicated by means of structural equation modeling. Multi-group analyses showed that intelligence, as hypothesized, functioned as a potential moderator with regard to the dimensional comparison processes. The results give valuable insights into possible reasons and prerequisites of dimensional comparison processes in the development of ability self-concepts.

Keywords

I/E model; Ability self-concept; Intelligence; Moderator analysis

Intelligenz als potentieller Moderator des I/E-Modells

Eine explorative Untersuchung

Zusammenfassung

Das Internal/External Frame of Reference Model (I/E-Modell; Marsh, 1986) postuliert, dass sich Leistungsergebnisse vermittelt über interne (dimensionale)

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und externale (soziale) Vergleichsprozesse auf das Fähigkeitsselbstkonzept (FSK) auswirken. Bislang wurde jedoch selten der Frage nachgegangen, ob Personenmerkmale die im Modell postulierten Zusammenhänge moderieren. Die vorliegende Studie hat zum Ziel, Intelligenz als potentiellen Moderator der im I/E-Modell postulierten Zusammenhänge zu untersuchen. Zu diesem Zweck wurden die Noten in Deutsch und Mathematik sowie die entsprechenden Fähigkeitsselbstkonzepte (SESSKO; Schöne, Dickhäuser, Spinath, & Stiensmeier-Pelster, 2002) bei einer Stichprobe von $N = 342$ Schülerinnen und Schüler der gymnasialen Oberstufe (durchschnittliches Alter $M = 16.94$, $SD = 0.71$) untersucht. Die im I/E-Modell postulierten Vergleichsprozesse konnten mittels Strukturgleichungsmodellen repliziert werden. Mehr-Gruppen-Analysen zeigten, dass die Höhe der Intelligenz die Ausprägung der im I/E-Modell postulierten dimensional Vergleichs in der erwarteten Weise moderierte. Die Ergebnisse geben Hinweise auf mögliche Ursachen und Bedingungen dimensionaler Vergleichsprozesse bei der Genese des FSK.

Schlagwörter

I/E-Modell; Fähigkeitsselbstkonzept; Intelligenz; Moderator-Analyse

1. Introduction

Ability self-concept (ASC) is one of the key theoretical constructs in educational psychology (Marsh, Xu, & Martin, 2012), which can be explained by its relation to several educational outcomes, among them academic achievement (e.g., Steinmayr & Spinath, 2009a). The internal/external frame of reference (I/E) model by Marsh (1986) is currently one of the most prominent models serving to explain the emergence of ASC (Brunner, Lüdtke, & Trautwein, 2008). It posits that ASCs are formed by using both an internal and an external frame of reference. On the one hand, students conduct social comparisons, that is, they compare their own accomplishments with those of their classmates (external frame of reference). On the other hand, students evaluate their achievements in any particular subject in relation to their achievements in other subjects (internal/dimensional frame of reference). The validity of the model is well demonstrated and was shown for several nationalities (e.g., Marsh & Hau, 2004). However, the spectrum of the reported postulated associations between the different variables of the model varies widely. A recent meta-analysis demonstrated that this variability could not be accounted for by sampling error alone and identified several moderators (Möller, Pohlmann, Köller, & Marsh, 2009). However, this meta-analysis did not take into account any cognitive or motivational characteristics as potential moderators. This might be due to the fact that so far hardly any research on such potential moderators has been conducted. The aim of the present study is to investigate the moderating influence of intelligence on the dimensional comparisons as postulated by the I/E model.

1.1 The I/E model

The I/E model was developed by Herbert Marsh to explain the paradoxical finding that domain-specific academic self-concepts in math and verbal domains do not or only weakly correlate despite the well-known fact that mathematical and verbal abilities are medium to highly correlated (e.g., Marsh, 1986). Based on the latter finding, one would assume that the domain-specific self-concepts also positively correlate with each other as domain-specific self-concepts are highly correlated with achievement in the corresponding domain. The I/E model explains the low or non-existent correlations between mathematical and verbal self-concepts by assuming two comparison processes that are involved in the formation of domain-specific self-concepts. First, students are believed to be engaged in social comparison processes. Within an external frame of reference, they compare their own domain-specific ability with the corresponding ability of other students. The social comparison process leads to a positive correlation between students' performance in one domain and the corresponding self-concept. This is usually indicated by means of the correlation between performance measures (grades, standardized achievement measures, etc.) and ASCs. Möller et al. (2009) report an average correlation of $r = .43$ ($r = .35$) between math achievement and math self-concept (verbal achievement and verbal self-concept). When the authors analyzed the association within the I/E model path-analytically, they found an average path coefficient from math achievement (verbal achievement) to math self-concept (verbal self-concept) of $\beta = .61$ ($\beta = .49$).

Second, the I/E model postulates dimensional comparisons. Dimensional comparisons refer to an internal frame of reference and depict such comparison processes in which students compare their ability in two domains (Möller & Marsh, 2013). For example, if a person performs better in English than in math this dimensional comparison process will result in a negative evaluation of one's mathematical ability independent from the actual performance level this person has in math relative to others. Thus, the I/E model postulates a negative effect from students' performance in one domain to students' ASC in the other domain. These processes are especially strong when internal comparisons are made between language and math/science domains (e.g., Marsh, 1986). Möller et al. (2009) found an average path coefficient from mathematical (verbal) achievement to verbal (mathematical) self-concept of $\beta = -.21$ ($\beta = -.27$).

As mentioned above, the validity of the I/E model was demonstrated in several nations (e.g., Marsh & Hau, 2004). The majority of research on the I/E model is correlational. There are also a few experimental or field-experimental approaches that supported the validity of the I/E model (e.g., Miller, 2000; Möller & Köller, 1998; Rost, Dickhäuser, Sparfeldt, & Schilling, 2004). Summing up, the validity of the I/E model has impressively been demonstrated (for an overview, cf. Möller & Marsh, 2013).

However, even though the broad majority of studies on the I/E model found effects in the hypothesized direction, the effect sizes greatly differ between studies.

The recent meta-analysis by Möller et al. (2009) identified several significant moderators such as the kind of achievement measure (grades vs. standardized achievement tests), self-belief measure (self-efficacy vs. ASC), year of publication, sample size, and years in school. Gender and country did not affect any path weights described in the I/E model. The significant moderators explained some of the variance in investigated effect sizes but not all. It might be that further variables moderate the associations depicted in the I/E model. The presented meta-analysis did not take into account any psychological person characteristics as moderators of the I/E model. The reason for this might be that, so far, single studies that explicitly investigated moderators of the I/E model are scarce. The following section provides an overview on studies investigating other moderators than those considered in the meta-analysis by Möller et al. (2009).

1.2 Person characteristics as moderators in the I/E model

Previous studies on the I/E model offer hardly any hints as to the interindividual differences that might play a role in moderating the strength of the influence of internal and external comparisons, respectively. However, some studies either investigated moderators of the relationships depicted in the I/E model or of the I/E model itself. Rost et al. (2004) showed that the ASCs for four different subjects in which students performed equally well were more positively correlated than the respective ASCs of students who got different marks in each subject. Skaalvik and Rankin (1992) obtained students' estimates of perceived ability for verbal and math skills. The ASCs of students who were convinced they were equally talented in both subject areas were more positively correlated than the ASCs of students who believed that they were differently talented. Möller, Pohlmann, Streblov, and Kauffmann (2002) found similar results for the subjective theories of students about the relationships between verbal and math skills in general. While controlling for the relevant subject grades the authors showed that the negative effects of performance in German on math ASC were more pronounced when students were convinced that verbal and math skills were rather distinct abilities in general. Summing up, constructs related to performance or beliefs about one's abilities seem to moderate the relationships depicted in the I/E model.

However, even though studies on moderators of the I/E model give valuable insights into the nature of the associations depicted in the model, there are not that many. A possible explanation for this evident lack of studies might be that research on the I/E model is exclusively conducted by educational psychologists and completely ignored by other sub-disciplines (Möller & Marsh, 2013). However, even if other sub-disciplines not explicitly investigate the I/E model, they focus on either the same or related constructs (e.g., research on self-concept as conducted by personality psychologists) or on the social and dimensional processes (e.g., research on social comparisons as conducted by social psychologists) depicted in the model. Thus, it might be valuable to consider research in related sub-disciplines to further

illuminate the conditions and effects of social and dimensional comparisons. Based on the research on the relation between intelligence and intelligence self-estimates (which are highly related with ability self-estimates; cf. Ackerman & Wolman, 2007), we consider intelligence as a potential moderator of the I/E model.

1.3 Intelligence as a potential moderator in the I/E model

A well-known definition of intelligence was provided by a panel of intelligence experts: “Individuals differ from one to another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought” (Neisser et al., 1996, p. 77). Thus, intelligence is the broad cognitive potential to learn and to solve problems in various settings which does not necessarily result in performance (cf. Sparfeldt, Schilling, & Rost, 2006). Intelligence should be differentiated from terms such as competence. Competencies are mostly defined by a person’s performance in a certain domain as a result of a learning process (cf. Blümke, Heene, Bipp, & Steinmayr, 2014). They cover cognitive dispositions related to performance that are functional in a specific context or with regard to specific demands and are often described as knowledge, specific abilities, and routines. Intelligence describes a person’s domain-general cognitive potential which does not necessarily result in performance (Hartig & Klieme, 2006). Thus, intelligence and competence vary at least in three important aspects (cf. Hartig & Klieme, 2006). First, the two constructs differ with regard to context. Intelligence is a broad intellectual ability necessary in most contexts and does not necessary require any already acquired knowledge. Competencies are related to situation-specific demands. Second, competencies are considered to be learn- and changeable, whereas intelligence is considered to be relatively stable. Third, the internal differentiation of both constructs differs. Intelligence is considered to be based on basic cognitive abilities, such as attention, whereas competencies are defined by means of the specific demands that should be mastered.

Intelligence self-estimations cover a person’s *beliefs* concerning his/her cognitive potential. Most often intelligence self-estimations are assessed by indicating on a bell curve depicting the distribution of a population’s intelligence scores how high people think their intelligence is. Both, general intelligence and intelligence self-estimates are important predictors of educational achievement outcomes (Bipp, Steinmayr, & Spinath, 2012; Kuncel, Hezlett, & Ones, 2004). The average correlation between general intelligence and school achievement is $r = .50$ (Kuncel et al., 2004). Thus, a person scoring high on general intelligence is likely to perform well in different school subjects. Various studies showed that intelligence scores positively correlate with both verbal and mathematical performance (Brunner et al., 2008; Steinmayr, Dinger, & Spinath, 2010).

The average correlation between intelligence scores and self-estimated intelligence is $r = .32$ (Freund & Kasten, 2012), with stronger correlations for numeri-

cal intelligence measures and self-estimates ($r = .42$) than for general intelligence (verbal and figural intelligence did not differ from general intelligence). This result suggests that people have at least some insight into the rank order of their intelligence compared to others. Furthermore, in recent studies the importance of general intelligence for the formation of a person's verbal and mathematical ASC was also demonstrated (Brunner et al., 2008; Chen, Hwang, Yeh, & Lin, 2012). The effects of intelligence on domain-specific ASCs even hold after controlling for performance in corresponding domain-specific achievement tests. Thus, persons with high intelligence scores are likely to have high domain-specific ASCs.

However, rank orders only tell one side of a story. Concerning the accuracy of intelligence self-estimations, research showed that subjects tend to overestimate their intelligence. Typically, intelligence self-estimates are 1 standard deviation (*SD*) above the actually measured intelligence score (Kaufman, 2012). A possible explanation for the overestimation of one's intelligence is the need to maintain optimistic self-judgments (Dunning, Meyerowitz, & Holzberg, 1989). This motivation for cognitive positive distortion of one's actual abilities is functional as a positive self-concept is correlated with a variety of important life outcomes (cf. Marsh et al., 2012).

Furthermore, a person's intellectual level also influences the extent to which one distorts the perception of one's abilities. Previous research provided evidence that especially subjects with low ability tend to overestimate their abilities. For example, in a study by Dunning, Johnson, Ehrlinger, and Kruger (2003), students were asked to judge their performance in an upcoming exam. Students with exam scores in the 10th percentile estimated their scores to be in the 60th percentile, whereas students with exam scores in the 90th percentile accurately estimated their scores to be in the 90th percentile (Dunning et al., 2003). This ability-level effect was also demonstrated with regard to writing ability, humor (Kruger & Dunning, 1999), and intelligence (von Stumm, 2014). The effect seems especially pronounced when psychometric intelligence is considered. In the study by von Stumm (2014), students in the lowest intelligence quartile (average IQ = 83) overestimated their IQ by 20 IQ-points, whereas students in the highest intelligence quartile (IQ = 117) slightly underestimated their IQ.

There are two possible reasons for this ability-level effect regarding an accurate estimation of one's ability. First, it might be that persons with low ability have no insight in their abilities and are thus unable to accurately judge their abilities. Second, persons with low ability might be embarrassed and thus unwilling to admit that they have deficits (cf. Chambers & Windschitl, 2004; Dunning et al., 2003; Kruger & Dunning, 1999). Thus, the distorted perception of one's abilities serves one's self-maintenance. Therefore, lowly intelligent persons should be especially prone to a distorted self-perception in different, especially cognitive domains as intelligence is important in a variety of situations where cognitive potential is needed (cf. Neisser et al., 1996). It should be further noted that this kind of distortion does not necessarily have an effect on the correlation between ASC and the actual measured ability as the rank order of both constructs might not be influenced by

this kind of distortion. For example, in the study by von Stumm (2014) the intelligence self-estimations of the low ability group was, on average, consistently below the intelligence self-estimations of the more intelligent groups. It might be that a less capable person still realistically perceives that his/her abilities are lower compared to actual more able persons but underestimates the extent of the difference. Consequently, the rank orders in the ASCs must not necessarily change due to the ability-level distortion. Thus, we do not expect social comparisons as operationalized in the I/E model (by means of path weights which are based on a correlational approach) to be influenced by the ability level.

So far, we are not aware of any study that systematically investigated whether the depicted ability-level effect affects dimensional comparisons described in the I/E model. There are reasons to believe that the dimensional processes might be impacted by the fact that lowly performing people greatly overestimate their abilities as dimensional comparisons rely on a comparison of the absolute levels of one's abilities. Even though the reasons why people engage in dimensional comparisons are not well understood (cf. Möller & Marsh, 2013), two introspective studies by Möller and Husemann (2006) and Möller and Weber (2001) demonstrated that most of the dimensional comparisons resulted in an improved participants' self-concept in the better off domain and a diminished self-evaluations in the other domain. We consider the ASC formation of a relatively lowly able student. Presumably, the respective student does not perform very well in math and related domains as well as in verbal and related domains. Consequently, due to social comparisons, his/her ASCs in most domains are not very high. However, due to the fact that less able people tend to overestimate their abilities it might be that, on an absolute level, their self-concepts are higher than their actual performance. Thus, the ability-perceptions in all domains are already positively distorted through overestimations. As the ASCs in both domains are already positively distorted, it might be that the effects of the dimensional comparisons, which lead to a further positively distorted ASC in the better off and to a diminished self-perception in the worse domain, are not that pronounced any more for this student. Summing up, due to the fact that less able students have a more distorted view on their abilities than more intelligent students it is likely that dimensional comparisons are more pronounced for cognitively able than for less capable students.

In line with such a moderating influence are the results by Plucker and Stocking (2001) who found stronger dimensional comparisons (indicated by higher path weights) in a gifted sample than those that were found in the meta-analysis by Möller et al. (2009). Furthermore, in a study by Möller, Streblov, and Pohlmann (2002) that investigated students with learning disabilities the dimensional paths were lower than those usually found. These results indicate that, indeed, dimensional comparisons in highly intelligent samples are more pronounced whereas they are less pronounced in lowly able student cohorts. Thus, we assume that for more intelligent individuals, the paths from school grades to the divergent ASCs (dimensional comparisons) will be more pronounced than those for comparatively less intelligent individuals.

2. Method

2.1 Sample and procedure

The sample was recruited from a German school preparing children for university (*Gymnasium*; see also Steinmayr & Spinath, 2008, 2009a). The school was located in a mid-sized town in North Rhine-Westphalia and its pupils can be considered as the typical population of this type of school in Germany (i.e., the majority being Caucasian from medium to high socio-economic status homes). In three consecutive cohorts, 342 11th and 12th grade students were tested (204 female, 138 male). Students were free to choose most of their courses. Thus, data were not nested in classes. The mean age was $M = 16.94$ years ($SD = 0.71$; Range 16–19). Only students excused by a medical certificate did not take part in the testing.

Testing took place at school on a day especially reserved for extracurricular activities in autumn. Students were separated into groups of about 20 and tested by trained students and research assistants. Below, only those scales that are important for the present article are described.

2.2 Instruments

2.2.1 School achievement

Students were asked to bring a copy of their last report card (made anonymous). They received this report card about 3 months before the testing. Report cards for a total of $n = 336$ students were obtained. Even after intensive endeavors, which made it possible to match further 8 report cards, the report cards of $n = 6$ students could not be matched with their testing material (deviating from Steinmayr & Spinath, 2009a, where 14 report cards were still missing). School achievement in the present study was operationalized by means of the German and math grades. Grades in Germany range from 1 to 6 with 1 indicating an outstanding and 6 an insufficient performance. For a better understanding of the present analyses, math and German grades were reverse-coded so that higher scores represent better achievement. In order to control for possible frame of reference effects due to cohort affiliations, grades were z-transformed for each cohort separately.

2.2.2 ASC

We measured ASC domain-specifically with items from the SESSKO (Schöne, Dickhäuser, Spinath, & Stiensmeier-Pelster, 2002) scale. Students answered four items per domain on a 5-point scale, for example, “I am not talented (1) ... very talented (5) in math/German”; “I find it difficult (1) ... easy (5) to learn new things in math/German”; “I am capable of little (1) ... a lot (5) in math/German”. Internal

consistencies were $\alpha = .95$ for math ASC and $\alpha = .90$ for German ASC. ASCs for math and German were, like grades, z-transformed for each cohort separately.

2.2.3 Intelligence

Intelligence was assessed using the Intelligence-Structure-Test 2000-R (*Intelligenz-Struktur-Test 2000-R*, IST; Amthauer, Brocke, Liepmann, & Beauducel, 2001). The basic module of the test assesses verbal, numerical, and figural intelligence as well as a composite of these three intelligence facets interpreted as reasoning. Due to its close relationship to intelligence, reasoning is used as a proxy for general intelligence in the present study. The internal consistency of the test was $\alpha = .90$.

2.3 Moderator analysis

Data analyses were conducted by means of structural equation models (SEMs) using the AMOS 19.0 software package. For the assessment of model fit, we referred to the chi-square- and the corresponding p -value, Comparative-Fit-Index (CFI), as well as Root-Mean-Square-Error of Approximation (RMSEA; Beauducel & Wittmann, 2005). According to Browne and Cudeck (1993), a RMSEA $\leq .05$ indicates a very good model fit and a RMSEA $\leq .09$ is still an indicator for a reasonable error of approximation. According to Hu and Bentler (1995), it is difficult to provide a recommended range for the CFI because in some cases even a CFI $< .90$ can indicate a reasonable model fit. Usually one looks for a CFI $\geq .95$.

We tested the influence of possible moderators by means of multi-group analyses. First, we looked for the model fit of the typical I/E model (cf. Figure 1) in our complete sample. The model was specified by two correlated manifest variables (grades in German and math), two latent factors (ASC in math and German) which were indicated by eight observed variables (four items per ASC each), and eight error variables. In a second step, a median split on the intelligence measure was performed resulting in a relatively lowly and relatively highly intelligent group. We then tested the models for measurement group invariance to show that the instruments to measure ASC and the complete model function similarly in both groups. Differences between the model fits are assessed by testing the chi-square difference between both models. Groups differ from each other if the model with group-invariant measurement models offer a poorer model fit than the model with different parameter estimations for the measurement paths.

In case of measurement invariance, hypotheses concerning the internal and external comparisons specified in the I/E model were tested. This was done by constraining the paths indicating these comparisons in both groups. Again, a poorer model fit of the constrained model in comparison to the unconstrained model indicated differences in path weights between both groups. Further analyses dem-

onstrated whether the differences were due to internal or external comparisons or both.

2.4 Missing data

There were only small amounts of missing data for individual items (less than 1 %). Instead of concentrating on the sub-sample that completed all measurement occasions, we accounted for missing data by means of full information maximum likelihood (FIML) estimations. Thereby, we followed the recommendation to estimate missing data via the Full Information Maximum Likelihood (FIML) method (Enders, 2001), which is a model-based estimation.

3. Results

3.1 Descriptives

Table 1 lists means, standard deviations, and internal consistencies of all scales as well as their intercorrelations for the total sample.

Table 1: Means, standard deviations and Cronbach's Alpha for German and mathematical ability self-concepts, math and German grades, intelligence as well as the intercorrelations between these variables separately presented for the total sample

	Descriptives			Intercorrelations				
	<i>M</i>	<i>SD</i>	α	1.	2.	3.	4.	5.
<i>Total sample</i>								
Ability self-concept								
1. Math	3.12	1.02	.95	1.00	-.43	.68	.06	.46
2. German	3.70	0.75	.90		1.00	-.30	.25	-.17
Grades								
3. Math ^a	3.93	1.13	–			1.00	.30	.37
4. German ^a	4.21	0.82	–				1.00	.12
Moderator variables								
5. Intelligence ^b	110.54	18.01	.90					1.00

Notes. *M* = mean, *SD* = standard deviation, α = Cronbach's Alpha.

N = 342. ^a *N* = 336. ^b Coefficients for intelligence are based on raw scores. Intercorrelations rely on z-standardized grades and ability self-concept scores. Grades were reversed so that a better performance is indicated by a higher numeric grade.

Correlations $r \geq .11$, $p < .05$; correlations $r \geq .14$, $p < .01$.

ASC as well as grades in German lay above their equivalents in math. The negative correlation ($r = -.43$) between math and German ASC indicated a medium, negative relationship between both constructs. A medium, yet positive relationship was found between grades in math and German ($r = .30$). Math ASC was strongly correlated with math grades ($r = .68$), whereas the relationship between German ASC and German grades was only weak ($r = .25$). Intelligence correlated positively with the mathematical ASC ($r = .46$) and negatively with the ASC in German ($r = -.17$).

Table 2: Means, standard deviations, and Cronbach's Alpha for math and German ability self-concepts, math and German grades, intelligence as well as the intercorrelations between these variables separately presented for the lowly and highly intelligent groups

	Descriptives						Intercorrelations				
	<i>M</i>		<i>SD</i>		α		1.	2.	3.	4.	5.
	Low	High	Low	High	Low	High					
Intelligence groups											
Ability self-concept											
1. Math	2.80	3.49	0.92	1.02	.94	.95	1.00	-.29	.65	-.04	.22
2. German	3.81	3.57	0.68	0.81	.87	.92	-.55	1.00	-.13	.39	.03
Grades											
3. Math ^a	3.65	4.27	0.98	1.20	-	-	.64	-.42	1.00	.22	.15
4. German ^a	4.14	4.29	0.75	0.89	-	-	.10	.21	.34	1.00	.04
Moderator variables											
5. Intelligence	97.89	125.27	12.49	10.82	.78	.74	.46	-.19	.34	.13	1.00

Note. $n_{low} = 184$, $n_{high} = 158$.

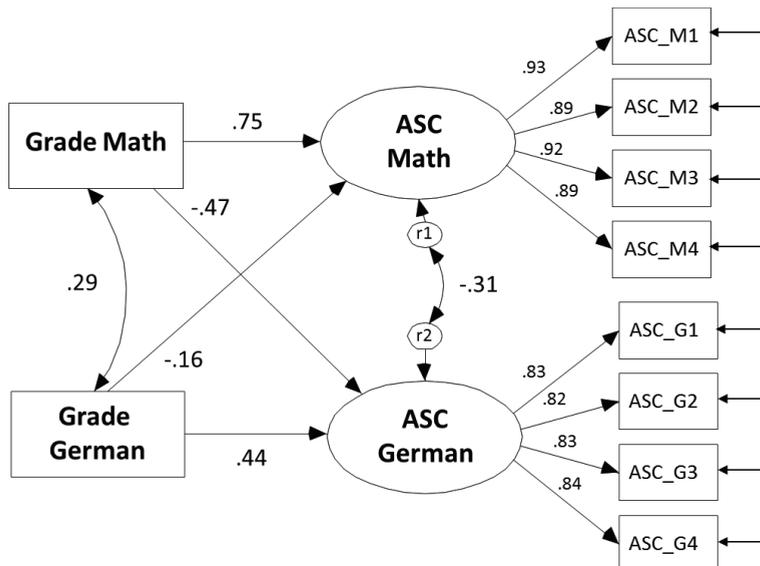
Intercorrelations rely on z-standardized grades and ability self-concept scores. Correlations above the diagonal are based on the lowly intelligent group's data. Correlations beneath the diagonal are based on the highly intelligent group's data. ^a Grades were reversed so that a better performance is indicated by a higher numeric grade. Correlations $r \geq |.15|$, $p < .05$; correlations $r \geq |.22|$, $p < .01$.

Table 2 presents means, standard deviations, and internal consistencies of all scales as well as their intercorrelations for both groups. To test for group differences, we conducted a MANOVA with intelligence group as a factor and German ASC, math ASC, German grades, and math grades as dependent variables. There was a significant main effect of group affiliation on these variables, $F(4, 328) = 11.87$, $p < .001$, $\eta^2 = .13$. Subsequently performed analyses of variance (ANOVAs) revealed that the highly intelligent group had higher values in all dependent variables with the exception of grades in German (math ASC: $F(1, 331) = 44.04$, $p < .001$, $\eta^2 = .12$; German ASC: $F(1, 331) = 8.95$, $p = .003$, $\eta^2 = .03$; math grades: $F(1, 331) = 26.69$, $p < .001$, $\eta^2 = .08$; German grades: $F(1, 331) = 3.08$, $p = .08$, $\eta^2 = .01$). Most interestingly, grades in German and math did not differ in the highly intelligent group ($t(174) = 0.25$, $p = .802$) but differed in the lowly intelligent group ($t(154) = 6.63$, $p < .001$). Lowly intelligent students had better grades in German than in math.

3.2 Structural equation modeling

To check on the I/E model, we first tested the model fit for the complete sample. The model had a good model fit ($\chi^2 = 45.74$, $df = 31$, $p = .04$; RMSEA = .04; CFI = .99). Math and German ASCs were determined by social ($b = .75$ and $b = .44$, respectively) as well as dimensional comparisons ($b = -.47$ and $b = -.16$, respectively; cf. Figure 1). Thus, the typical path coefficients postulated by the I/E model were also found in the present sample.

Figure 1: Standardized structural path coefficients as postulated in the I/E model and measurement weights for the total sample



Before multi-group analyses were performed the sample was subdivided by means of a median split. In order to judge the intelligence level of the investigated group we calculated standard scores for each subject. The average standard score for the total sample was $M = 108.15$ ($SD = 9.06$). Thus, the total sample scored on average about 1 standard deviation higher than a representative norm sample and its standard deviation was slightly restricted. The average standard score for the intelligence test (the test was standardized with $M = 100$ and $SD = 10$) of the “lowly” intelligent group was $M = 101.80$ ($SD = 5.89$), whereas the average standard score of the highly intelligent group was $M = 115.53$ ($SD = 5.99$). Thus, the “lowly” intelligent group had an average intelligence which was almost identical to the norm sample. The highly intelligent group scored on average about 1.5 standard deviations higher than the representative reference group. We then performed multi-group analyses. First, we tested for measurement invariance of the I/E model between the two samples. Second, we investigated whether the structural path weights in the I/E

model differed between those two groups. Table 3 shows the results of the multi-group comparisons.

Table 3: Fit indices for the general model and multi-group analyses as well as group comparisons between lowly and highly intelligent groups for measurement models and internal/external comparisons

Model		Fit indices					Multi-group analysis		
		χ^2	<i>df</i>	<i>p</i>	RMSEA	CFI	<i>df</i>	Δ CMIN	<i>p</i>
General		45.74	31	.04	.04	.99			
Moderated by intelligence	Model unconstrained	79.13	62	.07	.03	.99			
	Measurement model constrained	85.75	68	.07	.03	.99	6	6.62	.36
	Internal/external paths constrained	101.07	72	.01	.03	.99	4	15.32	.004
	External paths constrained	86.73	70	.09	.03	.99	2	0.98	.61
	Internal paths constrained	97.33	70	.02	.03	.99	2	11.58	.003

Note. $n_{low} = 184$, $n_{high} = 158$. RMSEA = Root-Mean-Square-Error of Approximation; CFI = Comparative-Fit-Index; Δ CMIN = test statistic of the chi-square (χ^2) difference tests.

Table 4 depicts the path coefficients of the I/E model for the different groups.

Table 4: Estimated (maximum likelihood) standardized path coefficients in the I/E model for the complete sample and the two intelligent groups

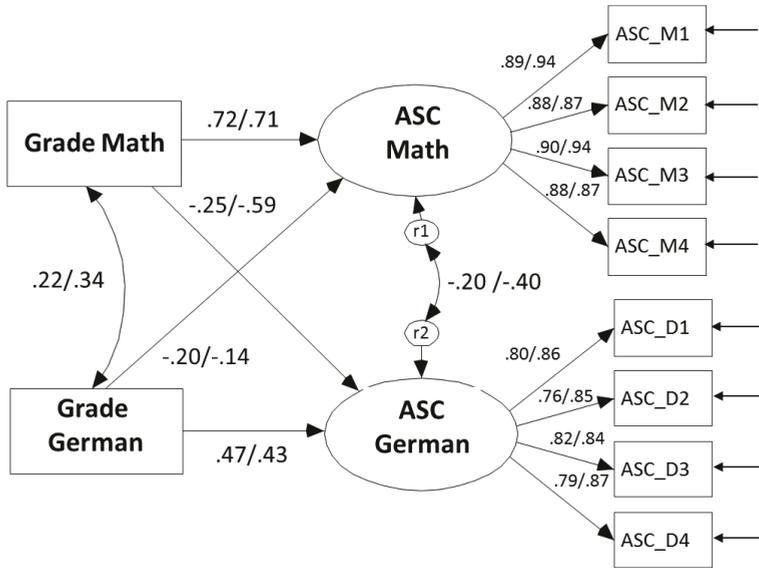
Model		Group		Social comparisons				Dimensional comparisons			
				1		2		3		4	
				β	<i>p</i>	β	<i>p</i>	β	<i>p</i>	β	<i>p</i>
I/E model		Complete	.75	<.001	.44	<.001	-.47	<.001	-.16	<.001	
I/E model moderated by intelligence		Low	.72	<.001	.47	<.001	-.25	<.001	-.20	<.001	
		High	.71	<.001	.43	<.001	-.59	<.001	-.14	.04	

Note. 1 = Path from math grade to ability self-concept in math; 2 = Path from grade in German to ability self-concept in German; 3 = Path from math grade to ability self-concept in German; 4 = Path from grade in German to ability self-concept in math.

The goodness of fit of the tested I/E model as well as the measurement invariance between compared groups were confirmed for both groups (see Table 3). In accordance with our expectations, the structural paths of the I/E model (cf. Figure 2) differed between comparatively more intelligent and less intelligent students (Δ CMIN = 15.32, *df* = 4, *p* = .004).

We then tested whether this effect was attributable to internal or external comparisons. This difference was fully attributed to internal comparisons ($\Delta\text{CMIN} = 11.58, df = 2, p = .003$), whereas groups did not differ in external comparisons ($\Delta\text{CMIN} = 0.98, df = 2, p = .61$).

Figure 2: Standardized structural path coefficients as postulated in the I/E model and measurement weights separately shown for the lowly and highly intelligent group



Note. On the left side, path weights of the lowly intelligent group and, on the right side, path weights of the highly intelligent group are pictured.

4. Discussion

4.1 General discussion

The present study investigated whether intelligence functioned as a moderator in the emergence of ASC in math and German. Our search for a potential moderator was inspired by the research on the accuracy of intelligence self-estimates (e.g., von Stumm, 2014) as well as by rationales how people engage in dimensional comparisons. Indeed, intelligence moderated the strength of internal comparison processes.

As demonstrated in a number of previous studies we confirmed the associations postulated in the I/E model by Marsh (1986) in the investigated sample. However, three unusual results occurred. First, the association between math achievement and math ASC was higher than between German achievement and ASC in German.

On the one hand, this might be explained by the fact that we used grades in German and not reading as often done in research on the I/E model. Performance in the subject German covers more than the narrow ability of reading and is not as well defined as performance in math which might make it harder to judge one's performance in this subject. On the other hand, German grades are not as stable as math grades (cf. Steinmayr & Spinath, 2009a). As achievement in German was indicated by grades given the semester before the testing, it might be that performance in German changed more than performance in math which led to the observed lower correlations.

Second, ASCs in German and math were unusually highly and negatively correlated. Möller et al. (2009) found an average correlation of $r = .11$ between the verbal and mathematical self-concept in their meta-analysis. However, the correlation found in the present study is comparable to the correlation found in a representative sample attending the same school type (*Gymnasium*; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2006) as the students in the present sample. Marsh et al. (2006) reported a correlation of $r = -.29$ between the verbal and mathematical ASCs in a comparable sample. Two aspects might have led to the fact that in both studies the ASCs were unusually highly correlated. First, in both studies, students were relatively old (between 16 and 19). A recent meta-analysis demonstrated that in samples with older students correlations between verbal and mathematical ASCs are on average lower than for younger students (Möller et al., 2009). Checking single studies with older students reveals that this lower correlation is due to the fact that some of those studies found negative correlations between verbal and mathematical ASCs as we found (e.g., Marsh et al., 2006; Steinmayr & Spinath, 2009a). Second, students were tested at a relatively late point in their scholastic career. At this point in time, students in Germany are allowed to make some choices concerning the classes they attend. Even though they all have to attend German and math classes, they can choose if these courses are advanced or basic. Furthermore, they are allowed to put an emphasis on verbal and related domains or on science classes. It might be that, additionally to the age effect (cf. Möller et al., 2009), the more students are allowed to follow a track that suits their interest in one of those domains, the more people think of themselves as "either math persons or verbal persons" (Marsh & Hau, 2004, p. 57). Thus, in such samples the ASCs are more negatively correlated than in younger samples that are usually not allowed to choose. Further studies should investigate if ASCs in verbal and mathematical domains become more negatively related when students are allowed to make choices, for example, investigating college students that either choose a subject related to science or one related to languages and social sciences.

The third unusual result concerns the negative path from math grade to the German ASC which was unusually high ($b = -.47$). This was also true for the bivariate correlation between math grades and German ASC ($r = -.30$). In their meta-analysis, Möller et al. (2009) report an average path weight of $b = -.21$ from math achievement to the verbal self-concept and an average bivariate correlation of $r = .09$ (if PISA data were excluded) between the two variables. However,

even though the magnitude of these associations found in the present study seem to be unusual they correspond to results found in comparable samples. Kessels and Steinmayr (2013) also found a stronger correlation between math grades and German ASC ($r = -.19$) in a sample of 630 students attending the same kind of school as in the present study than between grades in German and the mathematical ASC ($r = -.06$; not significant). It seems that in the highest track of the German school system, the *Gymnasium*, math grades are especially important for the formation of ASCs in German. Our study further qualifies this result as we demonstrated that this unusually high negative association was only attributable to the higher end of the intelligence distribution. For students having an average intelligence standard score, compared to a representative norm sample, we found a path weight ($b = -.25$) which was nearly identical to the one found by Möller et al. (2009).

The question remains why math grades negatively impact German ASCs in more intelligent samples. We hypothesized that dimensional comparisons in general are more pronounced for more intelligent students than for those of lower intelligence. However, we only demonstrated this effect for math grades. This means that in the highly intelligent group being good in math leads to a more diminished self-concept in German than in the lowly intelligent group. Or, the other way round, being bad in math leads to a more enhanced ASC in German in the highly intelligent group. It seems that especially for highly intelligent individuals math performance seems to be very important for the formation of their German (and mathematical) self-concepts. Research on intelligence self-estimates demonstrated that measured numerical intelligence and numerical intelligence self-perceptions are higher related to overall intelligence self-estimates than verbal or spatial intelligence measures or self-estimates (e.g., Furnham, Wytykowska, & Petrides, 2005; Steinmayr & Spinath, 2009b). This effect seems to be especially pronounced in gifted samples (Chan, 2001). Likewise, Rinn and Wininger (2007) found a high correlation between students' general school and mathematical ASC in a gifted sample. One might conclude that numerical or mathematical abilities and the perception of it are an important aspect in the self-formation of highly intelligent students. If dimensional comparisons serve a person's self-maintenance, a low mathematical performance should result in an especially enhanced verbal ASC in highly intelligent students as a low math performance seems to be especially threatening to one's self-worth in this ability range. On the other hand, if an above-average intelligent student is especially good at math this should result in an even more enhanced mathematical ASC and in a greatly diminished verbal self-concept that is less threatening to one's self-maintenance in this ability range.

Summing up, dimensional comparisons occur in all ability ranges and seem to be especially pronounced in more intelligent samples concerning the path from mathematical ability to German self-concepts. This means that in the end, all students have more or less distorted ASCs. However, research on the I/E model does not give much information on the extent of this distortion as the supposed social and dimensional comparisons processes are shown by means of a correlational ap-

proach and thus only refer to rank orders. It might be that, even though dimensional comparisons are partly more pronounced in highly intelligent samples, the absolute level of their self-perceptions is still more realistic than those of lowly intelligent samples (cf. von Stumm, 2014). As we did not assess ASC by means of a scale that assesses ASC with reference to the performance of a norm group or a certain criterion, we have no possibility to check whether the accuracy of ASCs of the two groups in the investigated sample differs. Future research should also assess domain-specific academic ASCs with scales that allow inferring how people judge their performance in comparison to other people (social reference approach) or with regard to a certain criterion. In this case, it would be possible to evaluate the extent to which social and dimensional comparison processes distort people's ASCs.

4.2 Limitations of the study

One limitation of the present study is the investigated sample. We solely investigated students from the highest track of the German school system. Consequently, the sample was recruited from the higher end of the ability distribution and was most comparable to a college student population. Thus, the sample was not population representative but represents the typical population of one specific school type. However, for the present study the sample was ideal as chances are very high that this kind of school is most likely to be attended by the most intelligent students. Investigating above-average intelligent students was crucial for the present study. Our median split resulted in two groups of which the one was comparable to the general population and the other scored, on average, 1.5 standard deviations higher than the average norm reference group. Thus, the latter group contained above-average intelligent and extremely intelligent students. It may be that the detected effects of the present study might only be replicated in a gifted or nearly gifted sample when giftedness is defined by an intelligence quotient of $IQ > 130$ (Wirthwein & Rost, 2011). This should be kept in mind when interpreting the present results. A further specialty of the investigated sample is the fact that we investigated three consecutive cohorts. Thus, the number of clusters (German and math courses) and teacher-student settings (as regards the grades received at the end of the previous school year) increased. We did not take these clusters into account due to the fact that the same students did not attend the same math and German classes but were unsystematically assigned to different German and math classes. A study by Lüdtke, Köller, Artelt, Stanat, and Baumert (2002) demonstrated that the class level, independent from the processes postulated in the I/E model, impacts the formation of ASCs in math and German. However, they did not investigate whether the class level moderated the path weights postulated in the I/E model. Based on the results in our study, this might be possible. Future studies should use samples as the one used by Lüdtke et al. (2002) to investigate the I/E model by means of hierarchical linear models as it might well be that class or school characteristics

(such as the average performance of a class or a school) influence the processed depicted in the I/E model.

A second limitation of the present study is that we used grades as an achievement measure. Unlike standardized achievement tests, grades are thought to cover more than pure conveyed knowledge, for example, also effort, motivation as well as several classroom and background variables (cf. Spinath, 2012). However, in the meta-analysis by Möller et al. (2009) the choice of the achievement indicator (grades vs. tests) did not influence dimensional comparison processes. Still, future research should replicate the presented results by considering achievement tests as achievement indicators. Especially, if effects on a second level (e.g., classroom level) are investigated it is mandatory to use standardized achievement tests as an achievement indicator as grades greatly suffer from social reference effects.

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