DIGIT RATIO AS A PREDICTOR OF LANGUAGE DEVELOPMENT AND MEDIA PREFERENCES IN KINDERGARTEN CHILDREN

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Summary: The role of prenatal testosterone (PT) in human behavior has increasingly been in the scope of psychoneuroendocrinological research in the recent years and has also been used to explain features of child (language) development. PT can be assessed by means of the so-called digit ratio 2D:4D, which is the ratio between the index (2nd digit) and the ring finger (4th digit). In the current paper, relations between PT, operationalized by means of 2D:4D, on the one hand and language development and media preferences (use of picture books) on the other hand in a sample of 190 three to four year-old children are reported. PT was significantly negatively associated with male as well as female performances in several language tests (e.g., language comprehension skills). In two analyses, 2D:4D was able to significantly distinguish between children of different developmental stages (normal vs. needing support vs. delayed). It was also found that, by trend, higher PT might be associated with less proneness to use picture books. It is concluded that PT is negatively associated with some features of language development as well as, potentially, with some early media preferences in pre-school age. Theoretical models of explanation and practical implications are discussed.

*Keywords***:** 2D:4D, digit ratio, kindergarten, language development, media preferences, pre-school age, prenatal testosterone, sex differences

Introduction

Research on the influence of hormones on human behavior plays a crucial role in the human sciences. The main focus lies on male sex hormones, the so-called androgens, especially on testosterone [Dabbs 2000]. In this kind of research it is important to distinguish between postnatally activating plasma testosterone and organizing prenatal testosterone (PT), with the latter showing its effect already during brain development [Beltz et al. 2013, Berenbaum, Beltz 2011, Falter et al. 2006]. As to the effects of postnatally activating testosterone on human and mainly «typical» male behavior, please refer to Dabbs [2000] and Kimura [2000].

One branch of recent psychoneuroendocrinological research (e.g., [Bailey, Hurd 2005, Falter et al. 2006, Lutchmaya et al. 2004]; for an overview see

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[Manning 2002]) has focused on the importance of PT and its organizing role in brain development and employed an indirect method of PT assessment, which is mostly referred to as 2D:4D. 2D:4D is the digit ratio that is calculated by means of the relation between the index (2nd digit) and the ring finger (4th digit). 2D:4D qualifies as an indicator of PT, because it could be shown that the longer the ring in relation to the index finger is, that is the lower 2D:4D is, the higher the testosterone exposure of the foetus was [Manning 2002]. Due to a higher exposure to PT, males have lower 2D:4D ratios on average than females (0.94 vs. 0.97 according to Bailey and Hurd [2005]). Hence, 2D:4D is a sexually dimorphic trait [Manning et al. 1998]. And because of the masculinizing effects of PT during brain development, 2D:4D should be able, at least partially, to explain behavioral and cognitive sex differences [Halpern 1997].

Studies found, for instance, a negative correlation between 2D:4D and aggressiveness: The lower 2D:4D, that is the more masculine 2D:4D, the higher the aggressiveness [Bailey, Hurd 2005, Hampson et al. 2008, Shaw et al. 2012, van der Meij et al. 2012] or assertiveness and dominance, respectively [Wilson 1983]. Athletic abilities are, according to the meta-analysis by Hönekopp and Schuster [2010], positively correlated with PT, measured by means of 2D:4D, too. Also, empathizing behavior (which is, on average, more pronounced in women than in men [Baron-Cohen 2003]) might be moderated by PT as assessed via 2D:4D [Kempe, Heffernan 2011, van Honk et al. 2011, Wakabayashi, Nakazawa 2010, but see Hönekopp 2012]. Two prominent sexually dimorphic cognitive abilities, namely mental rotation (with a male advantage of d = 0.70 according to the meta-analysis by Voyer [2010]) and verbal skills (with a female advantage in, for instance, speech production of $d = -0.33$ according to the meta-analysis by Hyde and Linn [1988]) are also associated with 2D:4D as expected [Burton et al. 2005; see also Collaer et al. 2007]. These findings are in accordance with research showing that also postnatal plasma testosterone has similar effects on visuo-spatial and verbal abilities [Christiansen, Knussmann 1987, Halpern 1997].

Recent research has also been increasingly occupied with the role of PT, assessed via 2D:4D, for childhood development. This is possible because the relation between the 2nd and the 4th digit is relatively stable from early childhood on [Albores-Gallo et al. 2009, Lutchmaya et al. 2004, Manning et al. 1998]. If PT has organizational effects on brain development in that it creates a «masculinized» brain instead of being merely a marker of postnatal plasma testosterone, one should expect to find correlations between 2D:4D on the one hand and human behavior and cognitive abilities on the other hand already in childhood.

Albores-Gallo et al. [2009], for instance, demonstrated in their study with children aged 1 to 4 years a relation between 2D:4D and vocabulary development. In accordance, Lutchmaya et al. [2002] reported a correlation between PT and vocabulary development, although they did not employ 2D:4D as a marker of PT. They found that the higher the PT exposure of the foetuses was, the less developed the vocabulary was at the age between 18 and 24 months. Brosnan [2008] reported in their study on 7-year-old children a positive relation between 2D:4D and reading and writing in girls as well as a negative relation between 2D:4D and numeracy skills in boys.

Also, PT plays a role for the aetiology of childhood disorders (e.g., [Martel et al. 2008, Liu et al. 2012, Williams et al. 2003]. Children suffering from autism, a disorder characterized by limited social abilities, have lower, that is more masculine, 2D:4D ratios than non-autistic children. This might explain why autism is strikingly over-represented among boys and men [Manning et al. 2001]. It is assumed that PT inhibits the development of some brain areas, especially in the left hemisphere, and thus causes such disorders [Geschwind, Galaburda 1987; but see Lust et al. 2010].

Despite these achievements (e.g., the study by Albores-Gallo et al. [2009]), to the author's knowledge no study exists that has examined the relation between 2D:4D and childhood language development in kindergarten age using a broad palette of (language) development diagnostic instruments. Hence, in the current study, the relation between 2D:4D and several language developmental dimensions in pre-school aged/ kindergarten children was examined. Even less is known about the relation between PT and early media preferences in young children. As there are some hints that certain media preferences in adults (e.g., movie genres [Schwab 2010]) are correlated with PT, it was tested whether there was a relation between children's proneness to use or play with picture books and their PT.

Methods

Participants were 190 children (100 boys, 90 girls) between the age of 3 and 4 years (M = 3.68, SD = 0.73). The children were tested in eight kindergartens in the German state of Hesse. 96 children were acquiring German as their first language (i.e., German was primarily spoken at home): 51 boys, 45 girls. 56 children were Caucasian white: 34 boys, 22 girls. Distinguishing between children of different ethnical background was important, as 2D:4D is confounded with ethnicity (Manning et al. 2007). In general, not all children participated in all tests. Thus, sample sizes varied depending on the test employed (see below).

Both hands of each child were scanned using a Canon CanoScan LiDE 25 scanner (scan mode: greyscale, resolution: 600 dpi, format: A4, file type: JPEG). For each hand, two scans were done, one with the fingers spread apart and one with fingers close together. Measurements were done by two research scientists independently from each other using a specifically programmed software allowing exact possible measurements. The scientists repeated each measurement once so that for each finger four values were obtained altogether. Reliability of the measurements was good to very good. As to the intra-rater reliabilities for each finger measurement, correlations were constantly above r = .9 and thus very good. For the statistical analysis, only the values for the right hand were used, because right 2D:4D might be a more valid marker for PT [Hönekopp, Watson 2010, Lutchmaya et al. 2004, Manning et al. 1998, Williams et al. 2003]. The respective values were created by using the means of the measurements of each of the two fingers of the right hand. As to inter-rater reliability, the right 2D:4D mean value based on the measurements of measurer 1 correlated with r = .87 with the right 2D:4D mean value based on the measurements of measurer 2 (N = 190 scans). The inter-rater reliability was thus good as well. The mean of the 2D:4D values obtained by the two measurers was used for the actual statistical analyses.

The following selection of (sub-)tests on language development was conducted: subtests «memorizing numbers» («Zahlen merken», assesses phonological memory), «explaining words» («Wörter erklären», assesses linguistic concept formation), «puppetry» («Puppenspiel», assesses language comprehension and verbal interaction, particularly comprehension of grammatical structures) from the *Wiener Entwicklungstest* (WET [Kastner-Koller, Deimann 2002]); subtests «sentence comprehension» and «phonological working memory for nonsense words» from the language development test *Sprachentwicklungstest für drei- bis fünfjährige Kinder* (SETK 3-5 [Grimm 2001]). For the relation between PT and the proneness to use picture books, a scale assessing the child's interaction with picture books from the test *Sprachentwicklung und Literacy bei deutschsprachig aufwachsenden Kindern* (SELDAK [Ulich, Mayr 2006]) was used. SELDAK is a test in form of an observation form that is used to study the language development of German speaking children. Among several scales, it consists of a scale on the autonomous use of picture books, which was used in the current study to cover the aspects of early media preferences. The instrument *Sprachverhalten und Interesse an Sprache bei Migrantenkindern in Kindertageseinrichtungen* (SISMIK [Ulich, Mayr 2003]) is comparable to SELDAK but used for children with migration background. SISMIK consists of several scales similar to SELDAK. One SISMIK scale covers the affinity for picture books, story-telling, and rhymes and is thus comparable to the SELDAK picture book scale. For the WET subtests, *C* values were used, that is centiles. The highest possible *C* value is 10 ($M = 5$, $SD = 2$). SETK subtests as well as the SELDAK and SISMIK scales use *T* values ($M = 50$, $SD = 10$).

The (sub-)sample sizes were as follows: WET subtest «memorizing numbers»: $n = 180$ (94 boys, 86 girls), WET subtest «explaining words»: $n = 177$ (94 boys, 83 girls), WET subtest «puppetry»: $n = 176$ (92 boys, 84 girls); SETK subtest «sentence comprehension»: $n = 178$ (93 boys, 85 girls), SETK subtest «phonological working memory for nonsense words»: $n = 181$ (94 boys, 87 girls); SELDAK scale on the autonomous use of picture books: $n = 20$ (11 boys, 9 girls); SISMIK scale on the affinity for picture books, story-telling, and rhymes: $n = 124$ (63 boys, 61 girls).

Inspired by Manning et al. [2000: 176] and due to the sometimes rather low size of some of the sub-samples, an alpha level of .10 was used as the anchor for deciding whether statistical significance was reached or not. This seemed appropriate considering the sometimes rather low sample sizes and the general fact that 2D:4D effects are mostly small (e.g., [Albores-Gallo et al. 2009, Hönekopp, Schuster 2010]).

Results

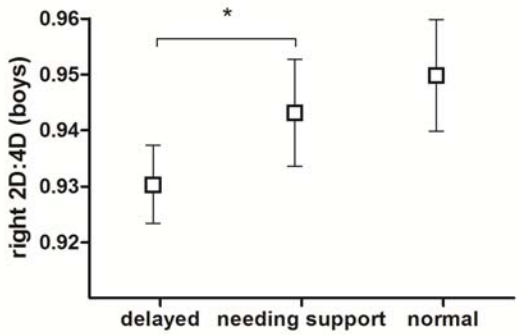
Right 2D:4D was normally distributed ($Z < 1$, $p = .20$). The sexes differed significantly and with moderate effect size from each other, with boys having lower values ($M = 0.938$, $SD = 0.025$) than girls ($M = 0.951$, $SD = 0.030$; $t = -3.226$, $p = .001$, $d = -0.47$).

As 2D:4D is hence confounded with sex, I examined, as other studies before (e.g., [Albores-Gallo et al. 2009]), the relation between 2D:4D and language developmental dimensions for each sex separately. The relation between

2D:4D and the performance in the WET subtest «memorizing numbers» was insignificant for boys as well as for girls (*p*s > .5). For the subtest «explaining words», the result was only marginally significant for boys with around 2% of explained variance ($p = .077$, $R_{korr}^2 = .023$). The relation between 2D:4D and the test score in «puppetry» (language comprehension and verbal interaction) was significant at a 1% alpha level in the male sub-sample in that lower PT was associated with better performance. 2D:4D explained almost 9% of performance variance after all ($p = .003$, $R_{korr}^2 = .085$). So, it is one distinctive result here that boys performed the better verbally (in «explaining words» and particularly «puppetry»), the lower the PT they were exposed to as foetuses was. For girls, however, the results were not significant.

The WET allows for a categorization of the children in those with normal development ($C \geq 4$), those needing pedagogical support ($C < 4$), and those with delayed development ($C < 2$). I hence tested whether 2D:4D could discriminate between the different groups (i.e., normal development vs. needing support vs. delayed development). For this purpose, I conducted ANOVAs separately for each sex with the three groups as the factor and right 2D:4D as the dependent variable. In the subtests «memorizing numbers», and «explaining words», neither for boys nor for girls was PT able to distinguish significantly between the three groups. For the subtest «puppetry», it was found that 2D:4D could significantly differentiate between the different groups (normal development vs. needing support vs. delayed development) within the subgroup of boys ($F_{(2,89)} = 5.216$, $p = .007$, $\eta_p^2 = .105$), with more masculine 2D:4D ratios being associated with language development problems (2D:4Ds = 0.930 for boys with delayed development, 0.943 for boys needing pedagogical support, and 0.950 for normally developed boys). As a post-hoc-test (LSD) revealed, the significant result in the ANOVA was qualified by the difference between boys with delayed development ($C < 2$) and those needing pedagogical support ($C < 4$) ($p = .025$). The effect size for this difference was moderate ($d = 0.53$). See Figure 1 for a graphical overview.

Fig. 1. 2D:4D differences between boys with delayed language development, boys needing pedagogical support, and boys with normal development regarding language comprehension and verbal interaction (WET subtest «puppetry», *C* values: < 2 vs. < 4 vs. ≥ 4)



Note. Error bars: 95% confidence interval. * $p < .05$

For girls, the results were similar at first sight: $F_{(2,81)} = 4.536$, $p = .014$, $\eta_p^2 = .101$. However, 2D:4D values were not in the correct ordinal order: 0.950 for girls with delayed development, 0.941 for girls needing pedagogical support, and 0.964 for normally developed girls. The difference between girls needing pedagogical support and normally developed girls was, however, in the predicted direction and statistically significant ($p = .004$) with a large effect size ($d = 0.83$). The pattern is that high PT is associated with deficits in language development or that low PT is associated with normal language development, respectively.

Next, the relation between PT and the scores in two SETK 3-5 subtests was examined. It was found that low PT was constantly associated with better language skills. In two out of four calculations, this association was significant or marginally significant with up to 5% of explained variance. Boys' (but not girls') performance in «sentence comprehension» was significantly predicted by 2D:4D ($p = .023$, $R_{korr}^2 = .045$). Girls' (but not boys') performance in «phonological working memory for nonsense words» was marginally significantly predicted by 2D:4D ($p = .083$, $R_{korr}^2 = .023$).

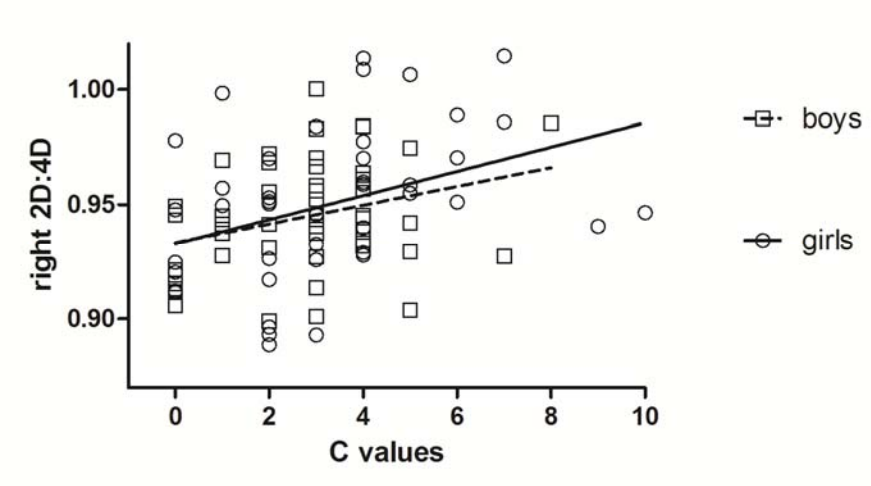
As to the SELDAK scale on the autonomous use of picture books, no significant result could be obtained. Sample sizes were relatively low though ($n = 20$). This was because SELDAK is for children growing up acquiring German. It was hence decided to administer SELDAK only to those children, for which it was certain that they were acquiring German as their mother tongue. The fact that many children in the sample had an immigrant background (see above) thus necessarily reduced sample size and statistical power as well for this test. This meant that even considerable effects might not have been statistically significant. And some effects were indeed large. For instance, for the picture book scale item «The child is fascinated by using the picture book», PT explained 11% of the variance for this item for girls (lower PT means higher interest in picture books). For SISMIK, the sample size was larger. Its scale covering the affinity for picture books, story-telling, and rhymes was examined too. However, neither for boys nor for girls, a significant effect of 2D:4D on this affinity could be found.

The use of different instruments for German and non-German children points to a critical facet: If children do not acquire German as their first language, then tests like WET or SETK, which are done in German and meant to be administered to German speaking children, are problematic. Moreover, whether PT explains differences in test scores in language tests then might be a negligible question, as German language input might instead be crucial. Hence, the analyses above were repeated employing only a subsample of children for which it was certain, based on a questionnaire for parents, that their family language was German ($N = 96$; 51 boys, 45 girls).

In the WET subtest «memorizing numbers», neither for boys nor for girls was 2D:4D a significant predictor (ps > .2). For «explaining words», the result was marginally significant for girls ($p = .08$, $R_{korr}^2 = .048$) but not for boys. In the subtest «puppetry», the result was highly significant for girls ($p = .01$, $R_{korr}^2 =$

.126) as well as significant for boys (p = .032, R_{korr}^2 = .075). See Figure 2 for a graphical overview.

Fig. 2. Scatterplots with regression lines showing the association between right 2D:4D in boys and girls in the German sub-sample and their performance in language comprehension and verbal interaction (WET subtest «puppetry», *C* values).



Again, it was tested whether PT was different between the three groups of children (normally developed, needing pedagogical support, delayed development; see above). In the subtest «memorizing numbers», neither for boys nor for girls was 2D:4D able to differentiate between the three groups (ps > .5). For «explaining words», the result for boys was not significant either. For girls there was a slight trend towards significance (p = .108). As sample size was rather low for the analyses here, it was worthwhile to rather focus on effect sizes. Indeed, explained variance was around 10% here (η_p^2 = .103). For girls in «puppetry», there was a significant result in the ANOVA ($F_{(2,41)}$ = 7.398, p = .002, η_p^2 = .265). However, the digit ratios were not entirely as expected (2D:4Ds = normally developed: 0.969, needing pedagogical support: 0.931, delayed development: 0.941). Still, normal development was associated with low PT. In boys, the result in the ANOVA was marginally significant ($F_{(2,46)}$ = 2.449, p = .098, η_p^2 = .096). Still PT explains almost 10% of the variance. Digit ratios were as expected in that the higher the ratio was, the less developmental problems existed (2D:4Ds = normally developed: 0.950, needing pedagogical support: 0.948, delayed development: 0.932).

The test scores in the SETK subtest «sentence comprehension» was neither for boys nor for girls significantly predicted by 2D:4D. In the subtest «phonological working memory for nonsense words», however, there was a highly significant correlation in the predicted direction (p = .004, R_{korr}^2 = .160) for girls, but not for boys. For SELDAK, no significant result was found. SISMIK test scores were not investigated, as SISMIK was only administered to children not growing up speaking German at home (see above).

2D:4D is not only confounded with sex, but also with ethnicity [Manning et al. 2007]. So, it is not only important to investigate 2D:4D for each sex separately in order to examine homogenous groups, but also to control for ethnicity. I hence conducted the previous analyses for Caucasian Whites only (n = 57). The analyses in this ethnically rather homogeneous group yielded basically similar results as in the other analyses. The following results were obtained. Neither for boys nor for girls was 2D:4D able to predict performance in the WET subtest «memorizing numbers». For «explaining words» 2D:4D could not explain performance in boys. In girls, the result was only marginally significant, but with around 10% of explained variance (p = .094, R_{korr}^2 = .101). As in all the analyses, low 2D:4D (i.e., high PT) was associated with worse language competence. For «puppetry», 2D:4D was able to explain 33% of performance variance in girls (p = .004, R_{korr}^2 = .334). In boys, the result was non-significant.

For the subtest «memorizing numbers», neither for boys nor for girls was 2D:4D able to differentiate between the three groups (normally developed, needing pedagogical support, delayed development) (ps > .6). In boys, 2D:4D was not able to significantly distinguish between the three groups (see above) in the WET subtests «explaining words» and «puppetry», either. Also in girls, the result for «explaining words» was insignificant. However, it was in the expected direction yielding a large effect ($F_{(2,17)}$ = 2.160, p = .146, η_p^2 = .203; 2D:4Ds = normally developed: 0.961, needing pedagogical support: 0.953, delayed development: 0.929). For girls' performance in «puppetry», 2D:4D significantly differentiated between the three groups ($F_{(2,17)}$ = 5.983, p = .011, η_p^2 = .413; 2D:4Ds = normally developed: 0.971, needing pedagogical support: 0.939, delayed development: 0.928). However, only the difference between normally developed girls and girls needing pedagogical support was statistically significant (p = .023). It yielded a large effect size though (d = 1.37).

In the SETK subtest «sentence comprehension», neither for boys nor for girls was 2D:4D able to predict performance (ps > .2). In the subtest «phonological working memory for nonsense words», however, 2D:4D was a very strong predictor of performance in girls. More than one third of performance variance was explained by 2D:4D (p = .002, R_{korr}^2 = .362). In boys, the result was non-significant.

Finally, 2D:4D as a predictor for the preference to play with picture books was examined. In boys, there was no significant result for the respective scale in the test SELDAK. In girls, however, there was an extraordinarily large effect: 2D:4D explained around 70% of preference variance (p = .049, R_{korr}^2 = .700). It has to be noted, though, that sample size was very small here (n = 3). In SISMIK, no significant results were obtained (ps > .5). See Table 1 for an overview of the results.

Table 1. Relation between right 2D:4D and test scores (in explained variance, R_{korr}^2), by sex of the child and (sub-)sample.

Entire sample (N = 190, 100 boys, 90 girls)								German sub-sample (n = 96, 51 boys, 45 girls)						Caucasian-white sub-sample (n = 56: 34 boys, 22 girls)						
Test \ Sex	MN	EW	P	SC	PM	SI	SE	MN	EW	P	SC	PM	SE	MN	EW	P	SC	PM	SI	SE
♂	–	.023	**.085**	**.045**	–	–	–	.010	–	**.075**	–	–	–	–	–	–	–	–	–	–
♀	–	–	.014	–	.023	–	–	–	.048	**.126**	–	**.160**	–	–	.101	**.334**	.031	**.362**	–	**.700**

Note. The tests were: MN = memorizing numbers, EW = explaining words, P = puppetry (WET); SC = sentence comprehension, PM = phonological working memory for nonsense words (SETK); SI = SISMIK picture book scale (children with immigrant background); SE = SELDAK picture book scale (German children). Only R_{korr}^2 values of at least .01 are presented. $p < .1$, **$p < .05$**, **$p < .01$**

Discussion

The current study examined the relation between 2D:4D, a sexually dimorphic marker of prenatal testosterone (PT), and language development as well as early media preferences (affinity to play with picture books) in kindergarten age.

2D:4D is a normally distributed trait in the population [Manning 2002]. The same applied to 2D:4D in the current sample. As expected, the sexes differed significantly from each other with moderate effect size with lower values for boys.

In general, verbal abilities were associated with low PT, as could be expected with previous research in mind (e.g., [Lutchmaya et al. 2002]). In some cases statistical significance was reached, in some cases not, depending on subsample sizes and effect sizes. Effect sizes were mostly small to moderate.

In the entire sample, 2D:4D explained between 5 to 9% of the variance in boys' language comprehension skills (subtests «sentence comprehension» or «puppetry»), respectively. This means that higher PT is associated with poorer performance in the respective subtest. In girls, the results were less clear when examining the entire sample (see Table 1). Looking at the German sub-sample and the Caucasian-white sample, 2D:4D seems to be rather more important for female than for male development with one third and more of explained variance. Although the sub-samples had a rather low size, they were probably better suited for providing valid results than the entire sample, as confounding factors (e.g., ethnicity) were excluded. So, especially in girls relatively high levels of PT might be disadvantageous for language development.

It was also found that 2D:4D could differentiate between children of normal and not normal (needing support or delayed) development. This was most evident in the WET subtest «puppetry». In the entire sample, the result was significant for boys. For girls, the respective analysis yielded a significant result only in the ethnically homogenous sub-sample (cf. above). The pattern was that children with delayed development had lower 2D:4D ratios, that is a higher tes-

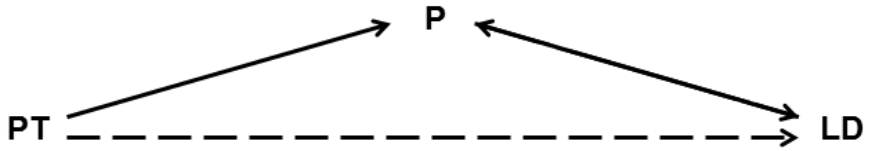
tosterone exposure in utero, or that normally developed children had higher 2D:4D ratios, that is a lower testosterone exposure in utero, respectively.

The results for early media preferences, that is the affinity to play with picture books, were not overall convincing. All results were in the predicted direction (low PT was associated with high affinity to play with picture books), but effect sizes were low. Moreover, sample sizes were low, which calls for further examinations of this issue using larger sample sizes.

The results on the relation between PT and language development are in general accordance with the Geschwind-Galaburda hypothesis [Geschwind, Galaburda 1987], which, *inter alia*, asserts that PT has negative effects on the development of the left hemisphere and thus distorts left-hemispheric abilities, which includes verbal abilities. However, the Geschwind-Galaburda hypothesis is controversial [Lust et al. 2010].

So, although numerous findings on the relation between 2D:4D and behavior-related correlates exist [Manning 2002], some questions on the nature of the mechanism behind this relation remain unanswered. It can be speculated that PT not directly influences the development of cognitive abilities but that it only shapes certain preferences, such as regarding playing behavior [Alexander, Saenz 2012, Beltz et al. 2013, Berenbaum, Beltz 2011, Ceci et al. 2009, see also Berenbaum et al. 2012, Valla, Ceci 2011]. These preferences might then have training effects in the respective cognitive and/ or developmental dimensions [Ceci et al. 2009, Valla, Ceci 2011]. Hence, for instance, the higher preference in girls for social interaction might be partially shaped by PT. And this preference could then possibly influence their language development, which is then advanced compared to the boys' one. Also the stage of language development, that is the language skills at a certain point in time, might influence one's preferences (see Figure 3). For instance, a child whose language skills are advanced enough for properly talking to its parents might develop an increased interest in actually talking as much as possible with its parents. This might then again have an effect on the child's language development.

Fig. 3. Assumed relations between prenatal testosterone (PT), preferences (P), and language development (LD).



Note. The dotted line indicates a potentially only indirect relation between PT and LD.

The pedagogical consequence could then be to encourage boys, despite or maybe even because of their higher PT on average, to engage in language-based social interactions. In the same breath, girls could be encouraged to participate in typical boyish activities. Psychological sex differences are mostly a matter of preferences and not a matter of abilities [Euler 2015]. However, preferences might turn into abilities, because the more a child is occupied with a certain

activity due to its affinity for this activity, the better she or he will be at this activity. This means that despite some biological causation within the language acquisition process, there is still potential to shape children's language skills towards preferable outcomes.

Acknowledgements
The author would like to thank AD, CW, EZ, and GGA for their support.

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