Chapter 1

Sex Differences as a Statistical Variable

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/66433

Abstract

Gender differences are often seen as either biologically determined or culturally acquired or conditioned. However, in an age where gender equality is the main target, neither peer reviewers nor students show much interest in gender differences. Moreover, not only do people try to integrate their 'ying' and 'yang' in their personalities also transgender identities are publicly acknowledged, appreciated and respected. Thus, in this chapter, I argue that we need to downgrade gender differences to a statistical variable that explains variance, sharpens statistical effects and reveals strategies. I am giving examples from my developmental psychology research where the split-sample analysis by gender showed amazing and often unexpected effects.

Keywords: theories on gender differences, split-sample analysis, sex differences in visual cognition

1. Introduction

Sex differences once were a popular topic, with extensive monographs on cognitive and social styles in the two sexes [1, 2] as well as on the development of boys versus girls [3]. This chapter is not trying to give an overview that is better covered in these volumes. Instead, an argument is developed that we should see sex differences as a statistical variable that may better explain data rather than give information about substantial differences between the sexes.

We have influential theories on the psychological differences between the sexes. I am introducing just three theories that in my view capture the most obvious sex differences. The 'extreme male brain theory' assumes that the difference is mainly cognitive-emotional insofar as males would be the better systematizers but suffer more from communication disorders such as autism (autistic spectrum disorder, ASD), while women would be the better empathizers [4, 5]. Baron-Cohen gives as a reason for the apparently increased systematizing capacity a prenatal surplus of testosterone with the consequence that boys with ASD can excel in visuospatial tasks such as the embedded figures test (EFT). However, this was not confirmed in another lab [6] and testosterone appeared to have more an effect on pre-school girls than boys [7]. Likewise, another recent study showed that men were just as caring as women and that caring was more dependent on marital status and ethnicity, educational achievement, income and the caring load [8]. Moreover, in a boy-only sample, boys with ASD were just as empathic as a control group of boys, and both were more empathic than boys with psychopathic tendencies [9]. It has even been suggested that the extreme male brain theory is based on a statistical artefact because strong systematizers such as engineers [10], but also violent men [11] tend to have more sons than daughters. Nevertheless, other follow-up research outside the lab of Baron-Cohen showed that this contrast between the sexes appears to hold as, for instance, males' brains do not zoom into distress sounds as promptly as those of women [12].

Another theory is that boys and girls segregate in order to keep separate cognitive and behavioural styles [13] in the same way as you would keep your distance to someone who does not behave to your liking. Importantly, Maccoby [[13, p. 173] describes that during the pre-school years, children change from a more fundamental belief in sex differences to a more probabilistic view of how a boy or a girl should behave. Children who belong to both gender camps would be very rare. She states that girls potentially have access to the boys' camp if they are physically strong and competitive (see also ref. [14]), while boys would have a harder life if they tried to enter the girls' camp where for instance turn-taking is important (see also ref. [15]). In a rather ingenious conclusion, Maccoby suggests that just this self-chosen segregation would make the construction of a shared script between the sexes necessary where expectations and styles can be negotiated. This 'being apart-coming together' theory is important because it explains why in some studies using the same tasks, we obtain significant sex differences, while in other samples we do not.

The third theory concerns female superiority in language processing, although it must be said that surprisingly no theory exists that would conceptualize it. Indeed, it is still not entirely explained why there seems to be a consistent female advantage in academic achievements but not in comparable ability tests [3, 16]. A recent study showed that only effort explains achievement in addition to ability, independently of gender [17]. Another explanation could be that ability tests may more often allow a spatially-based rather than language-based solution strategy [18], while language-formatted problems would be set more frequently during teaching in schools.

While some authors found that girls have better verbal skills [19, 20], there are surprisingly few recent empirical studies on this topic (see ref. [21]). According to Kimura's review [2], adult females do not have larger vocabularies or higher verbal intelligence than males, but they do have better verbal memory. It seems that girls appear to talk about and name everything as the language representations cover both sides of the brain, i.e. also the right side that processes language intonation, spatial cognition, mathematics, etc. while in boys fewer language representations were found in the non-verbal right half of the brain [22]. Men appear to be more hesitant before they say something [23]. Boys appear to prefer a purely non-verbal code if this is appropriate: In a spatial wayfinding task, girls used a spatial and a verbal strategy, that is across-modality double-encoding, while boys were more successful using an exclusively non-verbal strategy [24].

However, not all studies show so clear results in terms of sex differences in strategies. Very often there are two types of boys and this was often related to testosterone as the extreme male brain theory would predict. Maccoby and Jacklin [25] pointed out that intra-group variability within each sex may be larger than between-group variability amongst the two sexes; a view that was recently supported by Blakemore et al. [3]. Maccoby and Jacklin found that on average, boys with high testosterone had a lower IQ than boys with low testosterone. In a study on early language perception, male infants high in testosterone did not successfully discriminate between language sounds, while male infants low in testosterone showed sound discrimination that was left-lateralized, but all female infants showed successful sound discrimination with bilateral brain activation [26]. In this study, these results were revealed when a marginally significant interaction with sex of the infants was followed up with split-sample analyses not only for males and females separately, but also for the boys' sub-groups with high and low testosterone. Thus, this is an excellent example how sex as a statistical variable can explain variance, sharpen statistical effects and reveal cognitive style or deficits. However, with increasing age, these sex differences in language development dissipate relatively quickly with the onset of school [27–29]. However, this is not the case in spatial cognition.

2. Girls in detail, boys in shape

When we look at school-age children, the split-sample procedure holds a clear advantage over controlling just main effects of performance differences. In a study of Lange-Küttner and Ebersbach [30], 6- to 9-year old children were required to copy two cubes that were placed in front of them so that the first cube would be partially overlapping the second one. We also measured how well children could trace a shape in a noisy context (EFT), how well they could draw a horizontal water level into a tilted container (WLT) and how long it took them to decide whether two rotated 3D Lego cube aggregates were the same or not (MRT).

Children often gradually unfold all the sides of a cube in a schematic flat layout in their drawings before they integrate them into a projective depiction which accurately captures a three-dimensional view [31]. This achievement in school children is termed visual realism, while younger children would not draw what they see, but what they know (intellectual realism) [32]. For instance, at the very beginning of drawing, young children know that a cube is formed from square sides, so they just draw one square to denote the cube in their drawing, which has also been termed a minimalist approach [33]. But if each cube side has a different colour, young children draw all colours into this one square to illustrate the fact of this multi-coloured cube [34]. Hence, the fold-out layout is a transition phase between intellectual and visual realism. In our cube drawing experiment, we found that girls were much more likely to draw a fold-out representation of the cubes than boys (see **Figure 1**), with parts of the cubes proliferating beyond the actual amount of sides that were visible and invisible—as if they wanted to draw what could not be seen, but were unsure how much they could not see. Boys were more likely to extend the one-square drawing to a drawing with just two sides.

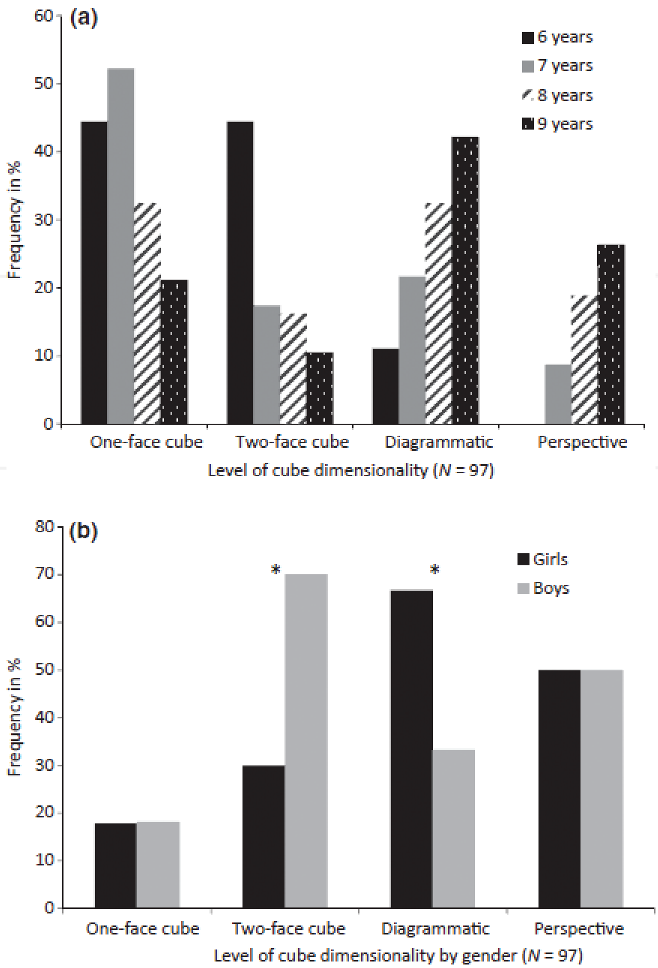

Figure 1. Frequency distribution of cube drawing levels by age (a) and gender (b) [30]. Copyright *British Psychological Society*.

We also controlled whether this proliferation of parts (see **Figure 2**) in the girls' drawings would occur because they had attended more to the surface structure of the painted Rubik's cubes, but this was not the case. Instead, only older children would attend less to surface details. Hence, we concluded that girls—like in human figure drawings [33, 35–37]—were drawing more detail. However, different to the human figure drawings where girls excel in detail, the details of the cubes had no names, still they would embark on laboriously drawing details in this cube drawing task. In contrast, boys appear to be more interested in drawing projective shapes, as they would focus more on the silhouette of an object whether animate or inanimate [33, 36, 38].

The silhouette, however, is what makes a figure-ground comparison easy, because there are no internal details and only the boundary or contour of the shape is relevant. Hence, it was not a surprise that the embedded figures test (EFT) was the only significant predictor in boys: the higher the boys scored in the EFT, the more likely they were to draw an advanced 3D drawing system. In contrast, the mental rotation test (MRT) was the only significant predictor in girls. Those girls who were at chance in judging the identity of rotated cube aggregates were also more likely to draw two non-occluded instead of overlapping one-face cubes. We do not yet know why boys are more focused on silhouettes unless one wanted to invoke Plato's cave allegory [39] where the inhabitants of a cave are fascinated by the differences in forms that are projected from the outside world on a cave wall and reject the 'real thing', that is the real-world objects. In contrast, girls would care about every detail of the real cube model, even those details that are surplus (commissions) and distort the visual shape of the cubes.

Importantly, in this study, if we had used an aggregate score summarizing the merits of their drawings and compared the overall achievement level, we may not have detected the sex differences in style and realism.

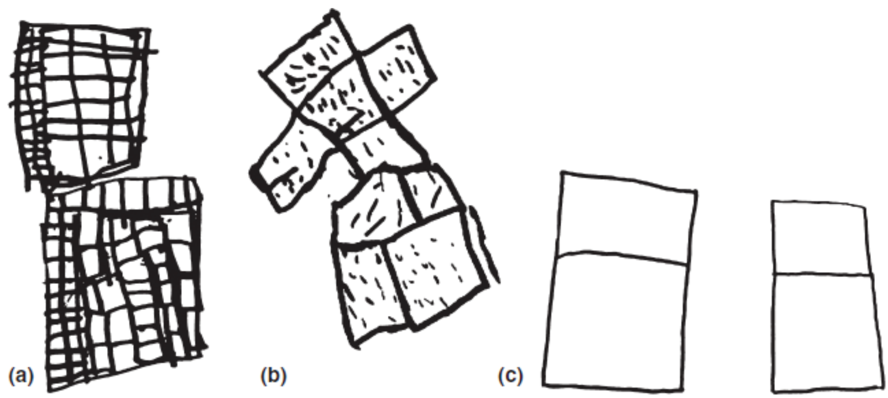

Figure 2. Examples of differentiated shapes for the occluding cubes. (a) Girl drawing the surface structure of the two cubes with sides attached top and left, (b) girl drawing a diagrammatic cube with some indication of surface structure but more clearly reinforced edges, (c) boy's drawing shows shape constancy when drawing the two cubes separately [30]. Copyright *British Psychological Society*.

3. Sex differences in spatial concepts: early achievement, action, delays and development

An even more striking example of the statistical power of the split-sample analysis with regard to sex differences is shown in a study of the development of visual memory in children [40]. In drawing, until about age 7, children allocate one place to one object (object-place binding), but when they become older, they are more likely to allocate an area to matching objects (objects-area binding) in a common region test (CRT) [41], see **Figure 3**. There are also always some children who do both at the same time, that is, they are inconsistent in using a spatial concept.

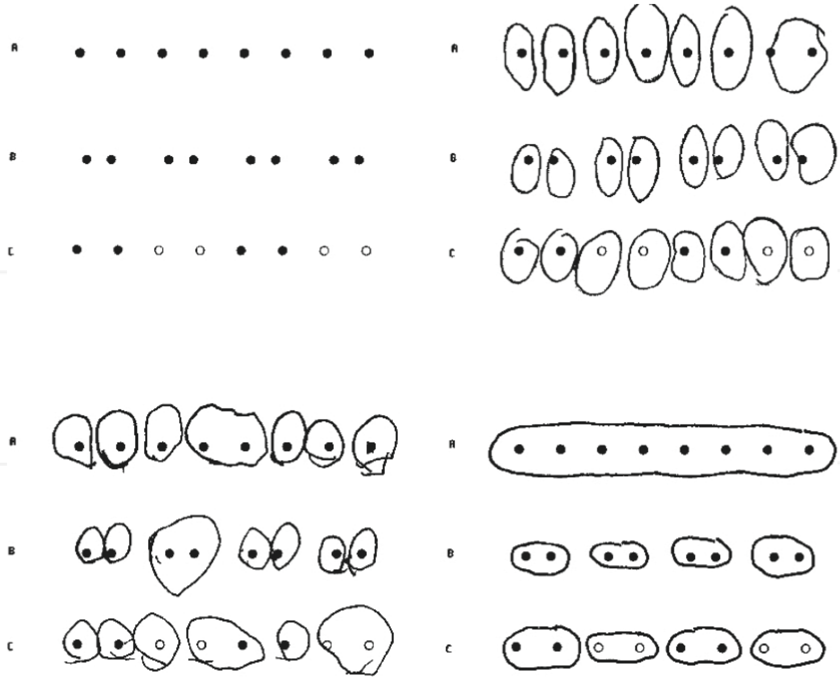

Figure 3. The common region test (CRT). The instruction was to circle those objects which children thought would belong together. Young children typically assign each object one place, older children more often assign a common region to matching dots, and some children assign spatial boundaries unsystematically [41]. Copyright *British Psychological Society*.

The intriguing result in terms of visuospatial cognition is that these drawing strategies predict visual memory. Those children who bind one object into one place are better in remembering shapes ('what'), while those who bind pairs of matching objects into an area are better in remembering places ('where') [42]. If the experimenter supplies those boundaries in the visual memory display on the computer, either a frame around a shape, or a spatial boundary around a number of objects, this explains the same variance as the drawing strategies [42]. A match between the allocation of space to objects in the CRT and the type of frame in the display enhances place learning [43].

Now in just one of my visual memory studies [40, 42] using this research paradigm, already the 6-year-old boys allocated spatial areas to several objects, while the girls did not, see **Figure 4**.

Boys from an economically disadvantaged background showed more often object-place binding, but object-region binding was equally likely to occur in all three male socio-economic groups. Differences due to male ethnic origin (Caucasian, African, Asian, mixed) did not reach significance.

Thus, 6-year-old boys from self-sufficient socio-economic backgrounds showed more awareness of spatial boundaries which in drawings usually emerge only around age 9 [44]. Boys from self-sufficient socio-economic backgrounds are also less dependent on colour cues in mental rotation tasks [45]. In addition, in visual memory accuracy, boys profited significantly more from an advanced spatial binding strategy than girls, whether they remembered shapes, or the places where these shapes were located, see **Figure 5**.

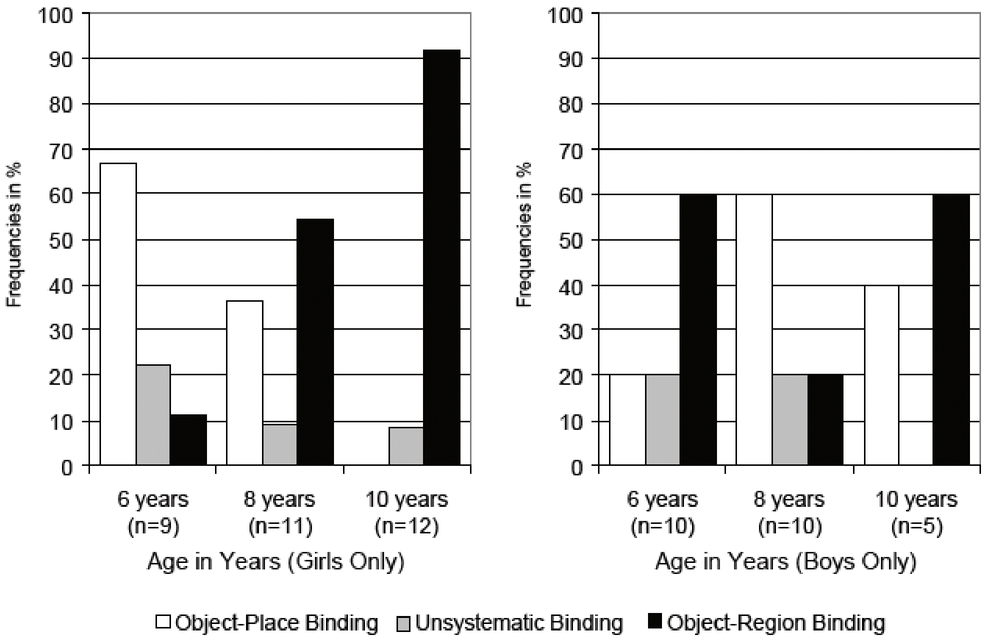

Figure 4. Girls (left) showed the predicted development from object-place binding to object-region binding, while boys (right) showed a U-shaped development for object-region-binding, with a later onset of object-place binding at age 8 [40, 42]. Copyright *European Journal of Developmental Science.*

Like in the other studies using this visual memory paradigm [42, 43, 46], also in the 2010a study, younger children remembered object shapes better than their places, see **Figure 6**. However, while this was significant for girls only at age 6 who could on average not remember a single place correctly, the shape priority in visual memory was still present in boys at age 8. The 8-year-old girls made a developmental leap in visuospatial cognition and now understood how to remember both shapes and places to the same level, while the 8-year-old boys were still more focused on shapes. Only at age 10, memory for object location was as good as memory for object shapes for both sexes.

In order to predict which factors were accountable for this delay in the transition from shape priority to spatial layouts of locations in boys, a spatial memory development index (SMDI) was computed by deducting the place recognition score from the shape recognition score. If the SMDI was positive, there was a shape priority, but if the SMDI was negative, place memory was better than shape memory. In general, the closer the score to zero, the smaller the difference between object shape and place memory. Sex, ethnicity, socio-economic status (SES) and age in months were the predictors in a multiple regression with the SMDI as dependent variable. For the whole sample, SES and age were significant predictors (see also Ref. [47], but in the sex split-sample, SES was a significant predictor in boys only, explaining 63% of the variance between boys. Age was a significant predictor in girls only, explaining 57% of the variance between girls.

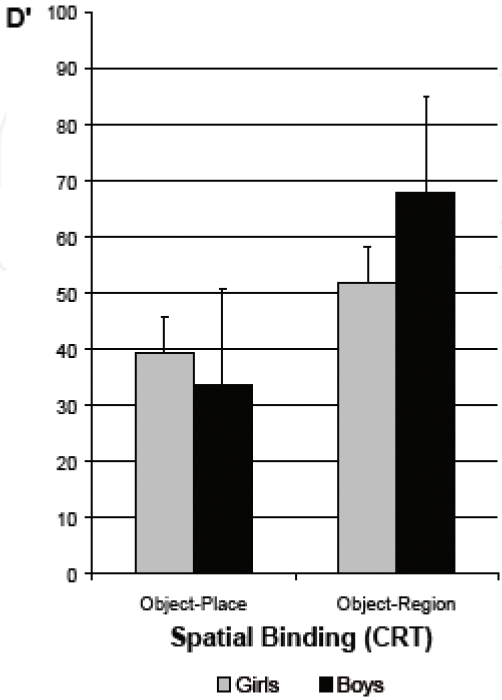

Figure 5. Spatial memory accuracy and spatial binding in the CRT. Boys showed a larger gain from object-region binding than girls [40, 42]. Copyright *European Journal of Developmental Science*.

Moreover, when the spatial strategies in the CRT were added, age explained now a whopping 88% of the variance in the SMDI in girls, but only 14% in boys. The significant effect of SES in boys was determined by the CRT, but the inclusion of the CRT did not reveal development with age. This shows that environmental factors such as SES can have a much larger effect on spatial strategies in boys than in girls. While the nature-nurture debate has made this issue a topic since a long time regardless of sex of the children, the result is nevertheless quite astonishing for developmental psychologists as children's spatial concepts are thought to universally develop with age [44, 48]. This particular study showed that in boys, advanced spatial strategies can occur early, but can also be comparably delayed, so much so, that overall no development with age can be found—which sheds new light on the universal validity or applicability of developmental theories.

While young children find it harder to remember the place of an object than its shape, to remember whether an object or figure is in a wrong place should require even more awareness of rules in spatial relations.

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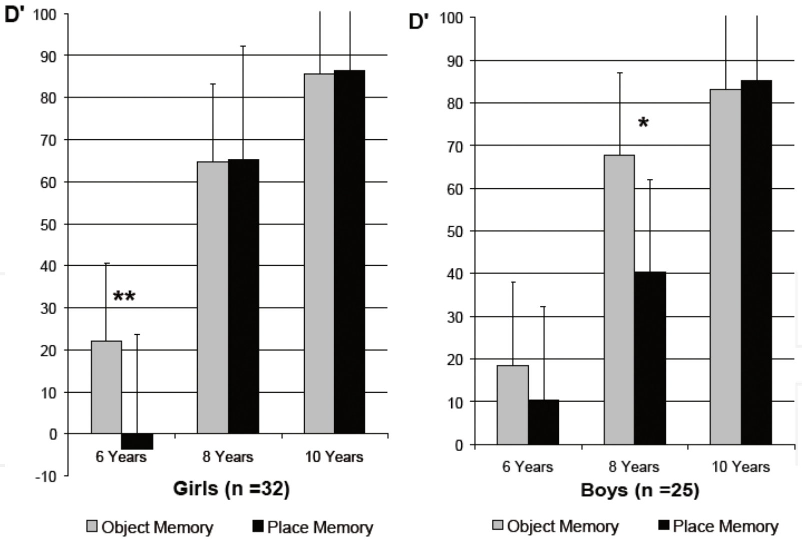

Figure 6. Object and place memory accuracy in boys and girls at ages 6, 8 and 10. Girls showed a significant gap between object and place memory at 6 years, boys at 8 years [40, 42]. Copyright *European Journal of Developmental Science*.

This is for instance the case when a football player is in a forbidden place in an offside position that is behind the defence line of the opposing team in front of the goal taking in unfair advantage. The crucial challenge when identifying an offside position is to recognize that the defence players can be grouped along an invisible spatial axis. In a very recent study, Bosco and myself investigated whether it is true what some male football professionals and reporters think, that is females do not make good referees in football [49]. Children are only gradually developing an understanding of spatial axes [44, 50, 51]. Hence, we taught 7–9-year-old children to identify an offside position with a Subbuteo set-up [52]. They drew the spatial positions of the players and the goalie as often until they got it right, see **Figure 7**. We then counted how many drawings they needed until they could draw a player figure in this wrong place. There were no significant sex differences in this task showing equal understanding when introduced to the offside rule.

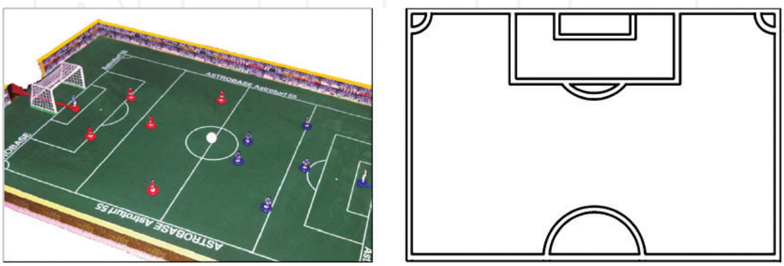

Figure 7. Left: Subbuteo game, Right: drawing sheet. The Subbuteo game was used to explain the offside rule to 7- and 9-year-old children. Children were drawing the offside position with pin men as often as required until they could create a correct depiction of the offside position. Achieving a correct drawing of the offside position was the criterion to be admitted to the offside rule computer task [52].

Once children had achieved this aim, they took part in a computerized visual search task where in 50% of the trials, a player was in an offside position, and in the other 50% of the trials, a player was not in an offside position, see **Figure 8**.

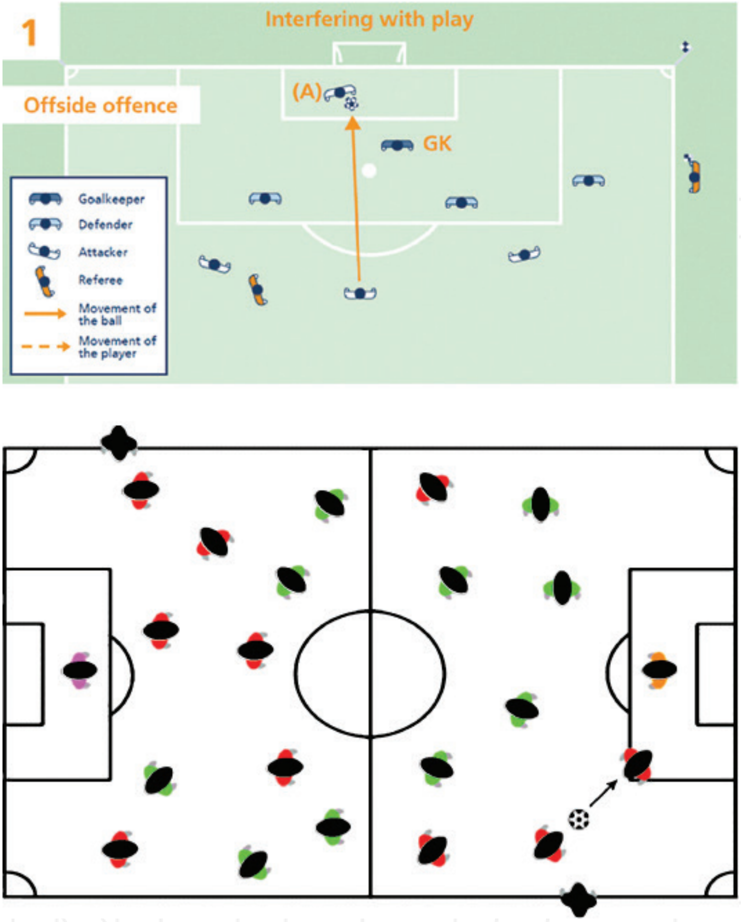

Figure 8. Top: FIFA playing field drawing [53, p. 112]. In the FIFA playing field, the offside player (A) in a white shirt stands *behind* the goal keeper (GK) and the light blue players who are his opponents. The player A is in an offside position because he is played at (the orange arrow), but not if the ball would have gone straight into the goal, passing him by. In this case, the arrow would have pointed towards the goal, not towards the player. Bottom: offside reaction time computer task. We adopted the arrow that points towards a player who may or may not be in an offside position. Children should either touch an offside player on the screen (48 trials), or touch the centre circle if there was no offside position (48 trials) [52].

Recognizing an offside position was easier than correctly rejecting a display where a player was not in an offside position, for both boys and girls, as it is for male adults [54]. However, boys reported that they were playing significantly more football games during the week than girls, with more than one-third of the girls playing football less than twice per month. When game experience was factored in as a covariate, it was revealed that in both age groups, boys were better and more consistent in identifying the offside position, see **Figure 9**. This result supports previous research on practice effects in spatial cognition with adults [55]. Nevertheless, it caused quite some furore in the press, some reporters focusing on the result that boys' football game experience made such as difference [56], while others capitalized on the fact that theoretically both sexes showed the same understanding and it was really just a matter of experience rather than sex of the participants [57]. Hence, the aim is now to run a study with a full factorial design, with one sample of children of both sexes from football clubs, and another sample of children of both sexes from communal libraries in the same community.

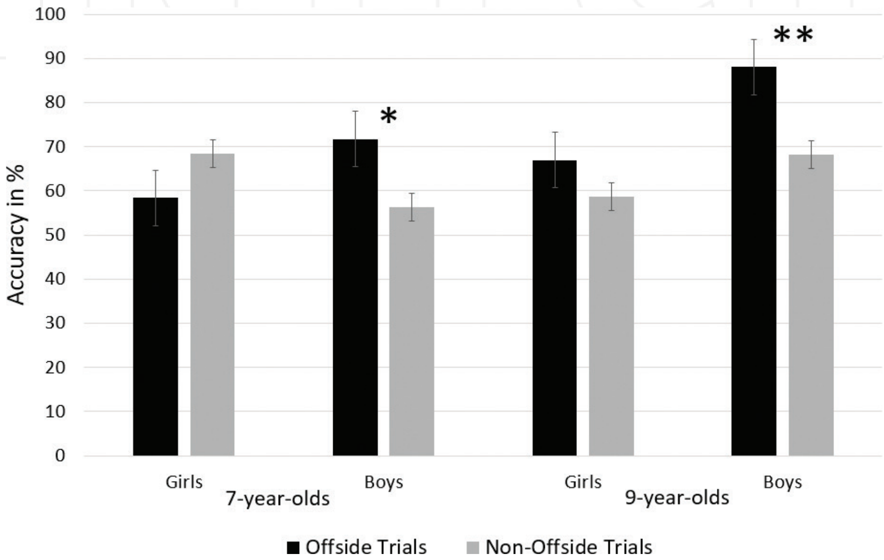

Figure 9. Only when the amount of ballgame experience was considered it showed that boys were better in making correct decisions about offside positions of designated players than girls, independently of age. Note. * = $p < 0.05$; ** = $p < 0.01$ [52].

4. Do only boys read with their eyes?

Now let us have a look at reading which is an activity where auditory and visual modalities need to be mapped with each other by allocating a sound to a visual sign called grapheme-phoneme mapping [58]. However, reading requires and supposedly develops visual cognitive ability for small detail [59, 69], for instance, discrimination of the letters d, b and p which all have the same visual components but in a different arrangement. Research with illiterates showed that visual reading strategies develop from raw visual perception to a strategy that distinguishes between letters and geometrically equivalent shapes and thus prioritizes alphabetic characters [61].

Huestegge et al. [59] used tests of short-term and long-term memory for small visual details and then compared boys and girls on these measures as well as on tests in reading proficiency and non-verbal IQ. In this sample, boys were the significantly better readers in the Neale Analysis of Reading Ability (NARA) test compared to girls, marginally so in terms of accuracy and significantly so in terms of understanding. Correlational analysis showed that they employed a visual cognition network, while girls did not, see **Figure 10**. In particular, Huestegge et al. found a significant reading advantage for boys who had scored high in the Benton drawing test, independently of IQ, which suggests that successful reading is supported by boys' interest in pen and paper, whether drawing or writing [62].

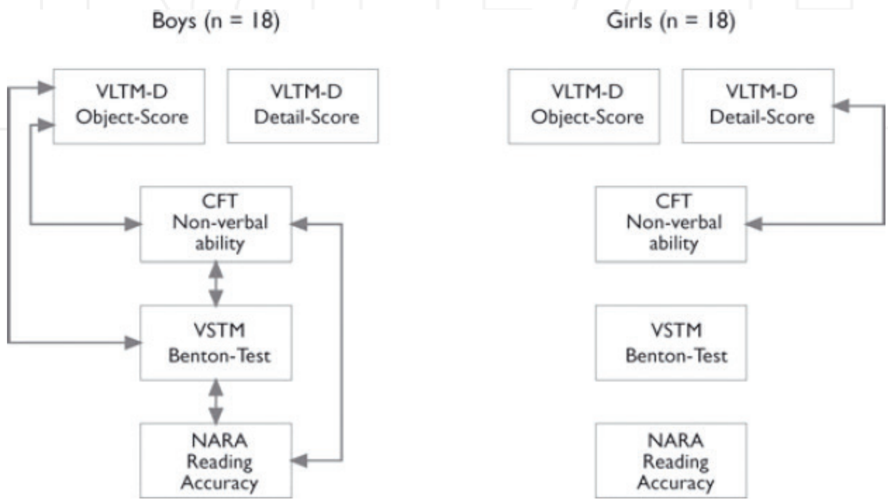

Figure 10. Pathway diagram of visual STM, visual LTM and non-verbal visual intelligence in relation to reading accuracy (gender-specific correlations) [59]. Copyright *British Psychological Society*.

Hence, also this study showed that the split-sample analysis revealed important clues how the task was solved by the two sexes. We demonstrated that boys can successfully use a visual strategy in an area where they are usually thought to be not quite as good as girls, and where they would even succumb to a stereotype threat [63]. Moreover, it is often thought that visual strategies in reading are detrimental because they would be necessarily wholistic [64].

5. Conclusions

In this chapter I have set out to argue that sex differences should be demoted to a statistical variable and the search for substantive differences between the sexes abandoned. I have selectively reviewed in detail some of my studies where we found sex differences in performance and only briefly mentioned those where none were found even if the same or similar tasks were used.

One conclusion from these studies is that sex differences in small samples are dependent on the interest of the particular participants in the samples. Girls with little interest in football are not as good as boys in identifying an offside position [52]. Boys who are interested in pen and paper are also good in reading [59]. If they are not interested in the content of what they read, boys show significantly poorer reading than girls who also thrived on low-interest material [65]. The important role of interest is recognized in the recent revision of a test that systematically assesses children's interest [66].

Content can also have the effect that training on a task such as the mental rotation task stays item-specific and does not generalize to other objects [67]. Moreover, more animate content (gymnasts) than the usual cube aggregates in the mental rotation task helps females to close the gap with males in the mental rotation task [68]. Women's mental rotation improved for both male and female figures, while men's mental rotation improved when stimuli were male figures, but not when they were female.

In developmental psychology, only the Neo-Piagetian theory captures the experiential factor in a systematic fashion. In contrast to Jean Piaget who was suspicious of statistics that went beyond frequencies, Neo-Piagetian theory is a concession to multivariate statistics to analyse multiple and multi-trial tasks. Neo-Piagetian theory was developed by Pascual-Leone in the late seventies and assumes a number of operators that provide the cogwheels of the mind, such as the M-operator for mental attentional energy, or the F-factor for field perception [69]. The specification of operators allows the researcher to select tasks that test the functioning of a particular factor.

Hence, training mental rotation is a task that specifically measures the functioning of the L-operator and allows us to decide that mental rotation is a task that measures the LC-operator (non-transferable item-specific experiential learning) and not the LM-operator (transferable logical-conceptual learning). However, also spatial memory which is supposed to depend on spatial concepts can be learned by repetition without the necessity of spatial strategies [46] as long as objects and places stay the same in repeated viewings. Moreover, the study on the understanding of the offside rule [52] showed that while the LC-operator was allowing boys to excel in the visual identification task of the wrong place, this did not prevent systematic judgement. In drawings, the LC-operator in combination with the F-operator would allow boys to avoid proliferation of detail so that the transition to viewpoint perspective and visual realism would involve just a small adjustment of contour [30, 33].

Hence, a second important conclusion of this chapter is that it is not always task difficulty as such that would be a suspect as a moderator for sex differences. On the contrary, we must make the assumption that the same tasks can be successfully solved in different ways. It is important to realize that there are best and best strategies which do not always yield significant sex-specific performance differences, but are only revealed in split-sample analyses. For developmental psychologists, this is somewhat new because we usually do find significant effects of age and task difficulty as children identify strategies which work [70]. Very few living psychologists acknowledge that children can intuitively and apparently effortless solve problems without understanding [71–73]; most contemporary developmental psychologists believe that the best and smartest strategy is effortful and discovered last by children.

In summary, this chapter shows that the combination of a minimalist approach and taking it easy while being selectively interested and active only in particular topics that are liked is a performance strategy that may produce more variance between children but can also lead to early achievements. Hence, it is important to see sex differences as a statistical variable rather than in a context which focuses on superiority.

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