

Haptic Parallelity Matching in Children and Adults

Hanneke I. Van Mier 

Department of Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, The Netherlands
Email: h.vanmier@maastrichtuniversity.nl

How to cite this paper: Van Mier, H. I. (2022). Haptic Parallelity Matching in Children and Adults. *Psychology*, 13, 631-646.
<https://doi.org/10.4236/psych.2022.135043>

Received: February 10, 2022
Accepted: May 13, 2022
Published: May 16, 2022

Copyright © 2022 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Research in adults has shown that performance is not veridical when participants have to set two bars parallel to each other haptically. It is hypothesized that this is due to the influence of the egocentric reference frame. In addition, larger deviations have been observed for oblique orientations compared to cardinal orientations and for female participants compared to male participants. So far, haptic parallelity performance in children has not been studied in detail. To close this gap the current study compared parallelity matching in children and adults, to address the question if the influence of the egocentric reference frame is the same in children and adults. The study included 120 participants, a group of 80 children, aged 9 to 11 years, and a group of 40 adults. In each group, half of the participants were male, the other half female. Blindfolded participants were instructed to make two bars, which were set in different orientations, haptically parallel to each other. They had to parallel the orientation of a reference bar which was felt with their non-dominant hand, at a test bar, that was rotated with their dominant hand. The bars were presented in the mid-horizontal plane at a distance that was set at twice the length of the arm of the participant. The dependent variable was the difference between the orientation of the reference bar and the test bar. The results showed similar deviations for children and adults. In both groups, a significant oblique and gender effect was found, although these effects were more pronounced in the adult group. These results suggest that children aged 9 to 11 years use the same reference frames as adults when paralleling two bars haptically.

Keywords

Haptic Spatial Perception, Egocentric, Allocentric, Gender, Children, Adults

1. Introduction

When asking adults if they think they would be able to (haptically) make two bars parallel to each other in the mid-horizontal plane with a (large) distance between the hands, most people think that they would be able to do so. Participants who performed such a parallelity task are often very surprised when they find out after the experiment that the bars are actually far from parallel (Kappers et al., 2008). What is asked from participants is to feel the orientation of a reference bar with their (non-)dominant hand and to simultaneously match this orientation on a test bar with their other hand. When performing this task with full vision and only using the hand to set the test bar, parallelity is indeed more or less obtained, with deviations being rather small, around 10° (Van Mier, 2020; 2021; Van Mier & Jiao, 2020). In such a condition, participants can use external allocentric cues from the environment, like the sides of the plates or table, walls, and door, to align the bars. The obtained deviations are thought to be the result of a (small) biasing effect from the egocentric eye- and/or head-centered reference frame (Kappers & Schakel, 2011; Van Mier, 2020, 2021; Van Mier & Jiao, 2020). However, when one has to perform the task haptically, so without vision, one has to rely more on an internal egocentric reference frame. In that case, the settings are often far from being parallel with deviations being on average around 40° , with some participants showing deviations up to 90° (Kappers, 1999, 2003; Van Mier, 2013, 2016, 2019, 2020, 2021; Van Mier & Jiao, 2020). When participants are confronted after the experiment with these large deviations in the haptic condition, they are very surprised because, as they state “their hands felt parallel” and they assumed the bars would therefore also be parallel. These observations show that the haptic perception of properties like orientation is distorted with respect to the physical reality. The rather large deviations are thought to be the result of the influence of the hand-centered egocentric reference frame (Van Mier, 2014).

When using an egocentric reference frame to extract spatial information about the orientation of the bar, the information is coded with respect to the person perceiving the orientation, with the own body as a reference. The egocentric reference frame in haptic parallelity matching is most likely hand-centred (Kappers & Viergever, 2006), as evidenced by the fact that the deviations are mainly directed in the natural orientation of the hand, being in a clockwise direction when the right hand is used to set the test bar and counter-clockwise when the left hand is used (Van Mier, 2014). When performing the task with vision, a more or less allocentric reference frame can and is most likely used. Allocentric referencing is applied when the orientation of the bar is coded in relation to objects external to the perceiver (Van Mier, 2014). In the haptic parallelity task, this most likely refers to the sides of the plates with the bars, the sides of the table, and/or the walls.

A distinction between ego and allocentric reference frames is supported by research that has shown that these frames can be differentially influenced by several factors. The observed deviations from parallelity in the above-described

task have been found to be intermediate between ego- and allocentric referencing (Kappers, 2002, 2003), and depend on the weighting of the two frames. The latter can be manipulated by different procedures or experiences (Kaas & Van Mier, 2006; Kappers, 2003; Van Mier, 2013, 2014, 2016, 2019, 2020; Van Mier & Jiao, 2020; Zuidhoek et al., 2003, 2007). The observed deviations are very robust as indicated by results showing that haptic or visual training or feedback had little or no effect on the deviations (Kappers et al., 2008). Only when visual conditions were included after haptic sessions, most likely stimulating the use of more allocentric processing, significant reductions in deviations were found (Van Mier, 2020; Van Mier & Jiao, 2020).

It has been found that the weighting is dependent on the gender of the participant, with a more egocentric weighting observed in women. It has consistently been shown that women have significantly larger deviations than men in haptic conditions (Hermens et al., 2006; Kaas & Van Mier, 2006; Kappers, 2003, 2007; Van Mier, 2013, 2016, 2019, 2020, 2021; Volcic et al., 2008; Zuidhoek et al., 2007). However, this gender inequality has mainly been observed in the traditional parallelity task. Stimulating the use of a more allocentric reference frame (Van Mier, 2013, 2016, 2020, 2021), reducing (Van Mier, 2013) or eliminating the motor response with the test hand (Kappers & Schakel, 2011; Van Mier, 2016), resulted in comparable deviations in both genders. These results discard an explanation that women are not able to use allocentric cues in haptic parallelity matching but support the idea of Zuidhoek and colleagues (2007) that women are more influenced by and less able to overcome the bias of the egocentric reference frame than men.

Weighting has also been shown to be influenced by the orientation of the bars. Research has shown an anisotropic phenomenon in haptic parallelity matching. It has been found that deviations for cardinal orientations (horizontal and vertical orientations of 0° and 90°) are significantly smaller than deviations for oblique orientations in haptic parallel matching tasks (Baud-Bovy & Gentaz, 2012; Gentaz & Hatwell, 1995; Gentaz et al., 2002; Hermens et al., 2006; Kaas & Van Mier, 2006; Kappers, 1999, 2002, 2003, 2004; Kappers & Viergever, 2006; Lechelt & Verenka, 1980; Van Mier, 2013, 2016, 2019; Volcic et al., 2007). It is hypothesized that vertical and horizontal orientations in a haptic parallelity task are more accurately processed due to experiences in the environment, where vertical and horizontal orientations are more common than oblique orientations (Gentaz et al., 2008). In addition, cardinal orientations are more frequently used as a reference norm than oblique orientations (Luyat & Gentaz, 2002; Spencer et al., 2006) and it is widely believed that orientations are represented in a reference frame using the vertical or horizontal orientations as principal axes (Gentaz et al., 2008).

The above-mentioned observations in haptic parallelity performance have all been established in adult participants. To the best of our knowledge, only one study has compared haptic parallelity matching in children and adults (Gentaz & Hatwell, 1995). The aim of that study was to establish if children would also

show an oblique effect as had been observed in adults. In this study, however, a short fixed distance of 40 cm between the bars was used and there were only 12 participants in each age group (7- to 8-year-olds, 9- to 10-year-olds, and adults) in the condition compared to the haptic parallelity task in the mid-horizontal plane. This study found significant differences between adults and children but no gender effects. The children also showed an oblique effect, although this effect was smaller than for the adults.

The current study was set up to compare haptic parallelity performance in a much larger group of children (80 participants) and adults (40 adults) than the before mentioned study. Additionally, a much larger distance between the bars was used than in the study by [Gentaz & Hatwell \(1995\)](#). In the current study, the distance was larger and modified for each participant by using twice the arm length of the participant, thereby making the distance proportionally the same for children and adults. The aim of the present study was to advance our understanding of the influence of the egocentric reference frame in haptic parallelity matching in children in late childhood. It was investigated if there would be an age-related difference in haptic parallelity performance between adults and children. In addition, we were interested in if a gender effect (boys having smaller deviations than girls), as well as an oblique effect (smaller deviations for cardinal than oblique orientations), would be observed in the children.

2. Method

2.1. Participants

A total of 120 participants were tested on the parallelity task. Participants were divided into two groups. The first group included 80 children, 40 boys, and 40 girls. The second group consisted of 40 adults, 20 men, and 20 women.

The ages of the children ranged from 9 to 11 years, with all children being either in 5th or 6th grade. Boys and girls had the same mean age of 10.6 years (SD = 0.73 for boys and 0.63 for girls, respectively). Thirty-two boys and 30 girls attended 5th grade, and 8 boys and 10 girls were in 6th grade. Children were attending primary schools in Belgian and Luxemburg. The majority of the children were Caucasian and from middle or high-class families. For the children written parental informed consent was obtained before the start of the study. The school received a small monetary reward for each child that participated in the study. The children received a small present for their participation.

The ages of the adult participants ranged from 20 to 85, with a mean age for the male participants of 31.6 years (SD = 16.3) and 32.0 years (SD = 16.5) for the female participants. Most of the adult participants were students at Maastricht University; the others were recruited among family and friends. Adult participants received a monetary voucher for their participation. All adult participants had given written informed consent prior to the study. The adult participants had participated in two previous studies by the author ([Van Mier, 2013, 2019](#)) which included the same set-up and orientations as used for the

children.

Annett's hand preference questionnaire was used to assess the hand dominance of the participants (Annett, 2004). The questionnaire was filled in before the study, with adults filling it in themselves, while one of the parents filled in the questionnaire for the children. For the latter handedness was additionally checked by the experimenter by asking the children to write their names. Most participants were right-handed, with the exception of five boys, two girls, and two women, who were left-handed.

Approval for the studies had been given by the ethics review committee of the Faculty of Psychology and Neuroscience of Maastricht University and they were performed in line with the ethical standards of the Helsinki Declaration of 1964.

2.2. Materials

Parallelity apparatus

The set-up to measure parallelity performance was the same as described elsewhere (Van Mier, 2013, 2016, 2019, 2020, 2021; Van Mier & Jiao, 2020) and consisted of two square metal plates of 30 by 30 cm with an aluminum bar positioned in the middle of the plate. An adhesive plastic layer with a printed 360° protractor, which had a radius of 10 cm, was attached to each plate (see Figure 1). The bars had a length of 20 cm and a diameter of 1.1 cm. Each bar had a small arrow-shaped point at one end to enable accurate setting and reading of the bars of about 0.5°. Rotation of the bar was made possible by a small pin attached in the middle of the bar that fitted in a small hole in the center of the protractor. Four magnets were attached to the bottom of the reference bar, to make sure participants would not accidentally rotate this bar. Two magnets were attached to the test bar (see Figure 1) to achieve the setting of precise orientations and at the same time increase resistance to accidental movements, avoiding over- and undershooting. To avoid movement or displacement of the boards, they were placed on anti-slip mats.

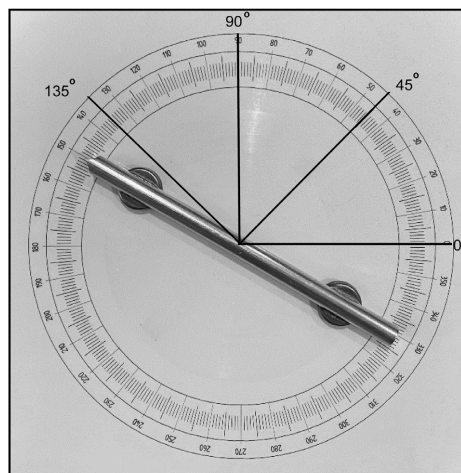


Figure 1. The protractor showing the test bar with the two magnets and the four orientations used in the study.

Raven's progressive matrices

To make sure that performance between boys and girls would not be related to differences in intellectual ability, children were tested on Raven's progressive matrices (Raven et al., 1992). This paper and pencil test is a standard nonverbal IQ test suitable for children. The test is short, easy to administer, and has been established as valid. It consists of 60 items, divided over 5 sets of 12 items each, progressing from easy to hard. Each item is presented as an abstract visual pattern from which a piece is missing. Displayed below the pattern are six (sets 1 and 2) or eight (sets 3 to 5) different pieces, and the child is instructed to select the missing piece that completes the pattern. The first three practice items, which are rather easy, were demonstrated by an experimenter and children received feedback on the answers. No points were scored for these items. For each correctly solved item, one point was assigned, resulting in a maximum score of 60. In the current study raw scores on the Raven's Progressive Matrices were used. The test was performed in school in groups, including children from the same grade. For most children, the test was performed before the experimental task, with only a few children taking the test after the haptic parallelity task.

2.3. Procedure

Although participants performed additional tasks or conditions, only the results of the haptic parallelity task will be reported here. The haptic parallelity task or condition was always performed first, during which participants were blindfolded. The instruction was to feel the orientation of the reference bar with the non-dominant hand and to parallel this orientation on the test bar by rotating the bar with the dominant hand. For right-handed participants, the reference bar was positioned on the left, and for left-handed participants on the right. Participants had to place both hands simultaneously on the bars, and were instructed to feel and rotate the test bar with their stretched hands (see Van Mier, 2019). It was observed that not all children fulfilled the latter requirement.

To study the oblique effect two cardinal (0° and 90°) and two oblique (45° and 135°) orientations were used (see Figure 1). Each orientation was presented three times. The order and repetition of the orientations were randomized for each participant, taking into account that the same orientation was never presented consecutively. Participants did not know which orientations were used and that they were repeated. For each trial, the experimenter positioned the test bar at a neutral position of either 70° or 120° . Before starting with the haptic parallelity task, all participants were tested regarding their understanding of parallelity by instructing them to line up two pens in such a way that they were parallel to each other using different orientations. Parallelity was demonstrated to the children by the experimenter and they were asked to position the pens in such a way that they were pointing in the same direction to make sure that they fully understood the concept of parallelism. After an understanding of parallelity was established, the length of the participant's arm was measured from the top of the shoulder to the wrist. The measured arm length was multiplied by two to

establish the distance between the centres of the boards resulting in a mean distance of 94.4 cm for boys, 94.0 cm for girls, 114.1 cm for men, and 102.6 cm for women. The adult participants who participated in one of the previous studies of the author (Van Mier, 2013) performed the haptic parallelity task at a distance of once and twice the arm length. For the current analyses, the results of the latter were used, a distance comparable to the distance used for the children and the adults in the other study (Van Mier, 2019).

The participants were seated at a table on which the boards with the protractor and bar were placed at an equal distance from the midline of the participant's body. The height of the table and/or chair was adjusted so all participants could comfortably feel and rotate the bars. Children were individually tested in an empty (class) room. Participants were told that instead of pens they had to set two bars in the same direction, which were positioned at the left and right side of the body. Because participants were blindfolded during the parallelity task, an experimenter positioned the participant's hands just above the bars. Participants did not receive feedback regarding their performance and there was no time constraint. Because of the latter, participants were asked to take their hands off the bars once they were satisfied with the result after which the experimenter noted the orientation of the test bar and positioned the reference bar at one of the other orientations, and the test bar at 70° or 120° for the next trial.

2.4. Statistical Analysis

Deviation, being the dependent variable in this study, was determined by subtracting the orientation of the test bar from the orientation of the reference bar. For right-handed participants deviations clockwise to the reference bar were noted as positive values, and deviations counterclockwise to the reference bar as negative values. For left-handed participants, clockwise deviations were noted as negative and counterclockwise as positive. For both children and adults, only 3% of the deviations were negative. Deviations were averaged over the three repetitions. A repeated measurement ANOVA was performed with Orientation (4: 0°, 45°, 90°, and 135°) as an independent within-subject factor and Group (2: adults and children) and Gender (2: male and female) as independent between-subject factors. Separate analyses were also performed for each group. Partial eta-squared (η_p^2) was used to calculate the effect size for orientation. Cohen's d was used to measure effect size when comparing the performance of the genders within the groups. Levene's tests showed homogeneity of error variances in both groups for all orientations. For post hoc comparisons between orientations, Bonferroni correction was used.

3. Results

3.1. Raven's Progressive Matrices Scores in Children

A one-way Anova was performed to check for differences between boys and girls in relation to IQ. This analysis showed that there was no significant difference

between boys and girls in relation to IQ as measured by the Raven's Progressive Matrices ($F(1, 79) = 2.198, p = 0.14$). Boys had an average score of 42.0 (SD = 5.3), girls of 43.9 (SD = 5.7).

3.2. Parallelity Performance

An overall repeated measurement ANOVA on the signed deviations including all variables showed a significant effect of orientation ($F(3, 348) = 26.299, p < 0.000, \eta_p^2 = 0.19$) due to much larger deviations for the oblique orientations than for the cardinal orientations ($0^\circ = 38.1^\circ, 45^\circ = 39.4^\circ, 90^\circ = 29.8^\circ, 135^\circ = 44.1^\circ$). Pairwise comparisons with Bonferroni correction showed significant differences between all orientations (all p 's < 0.002) except between 0° and 45° ($p = 1.0$). There was no significant effect of group ($F(1, 116) = 0.295, p = 0.588$) with children having a mean deviation of 38.5° (SD = 13.3) and adults of 37.2° (SD = 15.5). The effect of gender was significant ($F(1, 116) = 30.692, p < 0.000, \eta_p^2 = 0.21$). Male participants had a mean deviation of 31.1° while the mean deviation of the female participants was 44.7° . There was a significant interaction of group and orientation ($F(3, 348) = 4.639, p = 0.003$), as well as a significant interaction of group, gender and orientation ($F(3, 348) = 2.953, p = 0.033$). The latter can be seen in **Figure 2**.

3.3. Parallelity Performance in Adults

Because of these significant interactions, additional separate analyses were performed for each group. Starting with the results of the adults, a significant effect of orientation was found ($F(3, 114) = 12.819, p < 0.000, \eta_p^2 = 0.25$). Larger deviations were found for the oblique orientations than for the cardinal orientations ($0^\circ = 34.3^\circ, 45^\circ = 41.5^\circ, 90^\circ = 30.0^\circ, 135^\circ = 42.9^\circ$). Pairwise comparisons with Bonferroni correction showed significant differences between 0° and 45° ($p < 0.04$), between 0° and 135° ($p < 0.006$) and between 90° and 45° and 135°

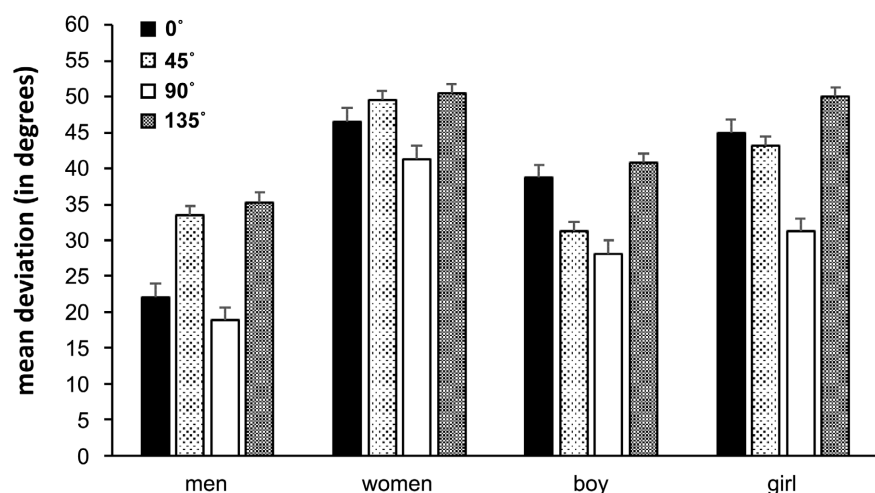


Figure 2. Mean deviations and standard error bars of the four orientations for men, women, boys, and girls.

(both $p < 0.001$). The mean effect of gender was also significant ($F(1, 38) = 28.087, p < 0.000$) (see **Figure 2**). Cohen's d was 1.29, showing a large effect size of gender in the adult group. The mean deviation for female participants was 47.0° , and for male participants 27.4° . There was no significant interaction between gender and orientation ($F(3, 114) = 1.881, p = 0.14$) (see **Figure 2**).

3.4. Parallelity Performance in Children

The effect of orientation was also significant for the children ($F(3, 234) = 23.586, p < 0.000, \eta_p^2 = 0.23$). The oblique effect was less pronounced in the children ($0^\circ = 41.8^\circ, 45^\circ = 37.2^\circ, 90^\circ = 29.7^\circ, 135^\circ = 45.4^\circ$). As can be seen in **Figure 2**, children had smaller deviations for the 45° orientation than for the horizontal 0° orientation. As seen in adults, the vertical 90° orientation was also best performed by the children. Pairwise comparisons with Bonferroni correction showed significant differences between 0° and 90° ($p < 0.001$), between 45° and 135° ($p < 0.001$) and between 90° and 45° and 135° ($p < 0.01$ and < 0.001 , respectively). The mean effect of gender was also significant ($F(1, 78) = 6.719, p = 0.011$) (see **Figure 2**). Cohen's d was 0.56, showing a medium but smaller effect size of gender for the children than for the adults. Girls had a mean deviation of 42.3° , boys of 34.7° . There was no significant interaction between gender and orientation ($F(3, 234) = 1.828, p = 0.14$) (see **Figure 2**).

4. Discussion

The current study was set up to explore the influence of the egocentric reference frame in haptic parallelity matching in children aged 9 to 11 years by comparing their performance to that of adults. It was shown that the deviations of the children were comparable to those of the adults. We replicated previous findings regarding the oblique and gender effect in a haptic parallelity task. It was found that deviations for cardinal orientations were significantly smaller than for oblique orientations and that the male participants were significantly better at haptic parallelity matching than the female participants. Analyses per group showed that while the oblique and gender effects were found in both adults and children, the effects were more pronounced in adults.

4.1. Age Effect

The data show that in the current study children and adults had comparable deviations. It was obtained that the deviations were mainly positive for adults as well as children. In each group, the majority of the settings were systematically oriented in the clockwise direction, so in the natural direction of the hands with only 3% of the settings being in the counter-clockwise direction (for right-handed participants, with the reverse for left-handed participants). This suggests that children most likely use the same reference frame as adults do, using a frame intermediate between ego- and allocentric referencing with the egocentric reference frame being biased by the hand. Contrary to our findings, **Gentaz and**

Hatwell (1995) found that in their study adults had significantly smaller deviations than children. These contradictory results might be due to the fact that in their study the distance between the bars was smaller (40 cm) and the same for children and adults. With children having shorter arms, the distance between the bars was proportionally larger for the children than for the adults. It has been shown that deviations increase when the distance between both bars increases in the horizontal plane (Fernández-Díaz & Travieso, 2011; Kaas & Van Mier, 2006; Kappers 1999, 2002, 2003; Kappers & Koenderink, 1999; Van Mier, 2013; Zuidhoek et al., 2003). Increasing the distance between the hands affects the orientation of the hands (Van Mier, 2014). Because we customized the distance between the plates based on twice the arm length of the participant, the distance was proportionally the same for all participants. This most likely resulted in comparable deviations between the adults and the children in the current study and might explain the different results between the current study and Gentaz and Hatwell's study.

Caution is needed, however, because there could be another reason that children in the current study performed comparably to adults. This might be related to the way they used their hand to turn the test bar. It was observed that some children sometimes used a different handgrip to orient the test bar. While all adults used their stretched-out hands to feel the reference bar and set the test bar, children sometimes used their fingers and thumb to rotate the test bar, a so-called finger-grip. This grip might have resulted in smaller deviations, due to a decrease in the influence of the egocentric reference frame. A significant difference in deviations in parallelity performance due to a change in hand position at the test bar has been found in adults in one of our previous studies (Van Mier, 2019). When rotating the test bar with the fingers and thumb, using the so-called finger-grip, deviations were significantly smaller than when rotating the test bar with the flat-stretched hand. It was hypothesized that in the latter case the biasing influence of the hand-centered egocentric reference frame was reduced, resulting in smaller deviations. Because it was not systemically documented which children used a finger grip and when during the experiment, it is not possible to examine this in more detail. Additional research is needed to find out if the current results could have been influenced by the different handgrips used by some of the children.

4.2. Gender Effect

The overall analysis showed a significant effect of gender in the current study, with male participants being better in haptic parallel matching than female participants. The significant effect of gender in the adults was expected, as this was already established in the participants from our former studies whose results were also used for the current study (Van Mier, 2013, 2019). This finding is consistent with reported results from previous studies including adult participants (Hermens et al., 2006; Kaas & Van Mier, 2006; Kappers, 2003, 2007; Van Mier,

2016, 2020, 2021; Volcic et al., 2008; Zuidhoek et al., 2007). Analyzing the effect size of gender for the current study showed that the effect size was large for the adults. A significant effect of gender was also observed for the children, with boys having smaller deviations than girls. This most likely was not the result of differences in IQ, because boys and girls had comparable scores on the Raven's Progressive Matrices. However, the effect size of gender was smaller for the children than for the adults, showing a medium effect size. This might be due to the fact that the haptic parallelity task has a spatial aspect. Our observation of a smaller gender effect in the children is in line with findings reported by Voyer et al. (1995). The authors reported higher gender effect sizes in adults than in younger children in spatial tasks, with more enhanced performance in male participants. Some research suggests that spatial processing is even more enhanced in males after sex hormones set in at puberty (Hassler, 1991; Davison & Susman, 2001). It is possible that this enhancement was not attained in the current study because most of the children were of pre-pubertal age. However, inconsistent results regarding the effect of hormonal changes in puberty on spatial processing have been reported with the evidence not always being straightforward (Berenbaum & Beltz, 2011; Liben et al., 2002). Additionally, it has been found that the haptic parallelity performance of female participants did not significantly differ from male participants when the response with the test hand was reduced or eliminated (Kappers & Schakel, 2011; Van Mier, 2013, 2016). The spatial aspects of these conditions are the same as when a response with the hand is needed. Therefore the explanation for the smaller gender effect in children related to hormonal changes in males seems less likely.

Another possible explanation for the smaller gender difference in children might be related to the use of a different handgrip by the children to orient the test bar. As stated above, some children sometimes used their fingers instead of their stretched hand to rotate the test bar. Manipulating the bar using the fingers has been shown to result in smaller deviations in adults (Van Mier, 2019), due to a decrease in the influence of the egocentric reference frame. It is possible that girls used this grip more often than boys, resulting in a smaller difference in deviations between boys and girls. Because these observations were not recorded for each child during the experiment but only recalled afterward, we can only hypothesize that this might have been the case.

Contrary to our findings, Gentaz and Hatwell (1995) did not observe a significant gender effect in their study. This might be due to the smaller sample size used (only 6 participants per gender in each age group and condition), or the use of a smaller distance between the bars. In the current study, the distance between the bars was more than twice the distance used in the study of Gentaz and Hatwell. Van Mier (2013) has shown that gender effects in adults were much smaller when a shorter distance (only once the arm length) between the bars was used. This might additionally explain the insignificant gender effect in Gentaz and Hatwell's study. It would be interesting to examine the effect of using a different

handgrip and/or a smaller distance between the bars in children in a follow-up study.

4.3. Oblique Effect

A significant effect of orientation was found in the current study, revealing an oblique effect, with overall smaller deviations for the horizontal and vertical orientations than for the oblique orientations. Again, this was expected for the adult group, as this had already been established for the adults (Van Mier, 2013, 2019) being consistent with findings reported in other studies (Baud-Bovy & Gentaz, 2012; Gentaz & Hatwell, 1995; Gentaz et al., 2002; Hermens et al., 2006; Kaas & Van Mier, 2006; Kappers, 1999, 2002, 2003, 2004; Kappers & Viergever, 2006; Lechelt & Verenka, 1980; Van Mier, 2016; Volcic et al., 2007). As stated in the introduction, it is hypothesized that due to experiences in the environment, where vertical and horizontal orientations are more common than oblique orientations, vertical and horizontal orientations in a haptic parallelity task are more accurately processed (Gentaz et al., 2008). It has also been found that cardinal orientations are more frequently used as a reference norm than oblique orientations (Luyat & Gentaz, 2002; Spencer et al., 2006) and it is widely believed that orientations are represented in a reference frame using the vertical or horizontal orientations as principal axes (Gentaz et al., 2008). The separate analysis including only the children showed a similar main effect of orientation. However, the significant group-by-orientation interaction indicated that the effect was different for adults and children. The results revealed that for adults both the horizontal and the vertical orientations were paralleled better than the oblique orientations. Children had also smaller deviations for the vertical orientation compared to the oblique orientations, but the horizontal orientation resulted in larger deviations than the oblique 45° orientation. The latter might be due to mechanical aspects which will be addressed later on. So, the oblique effect was less pronounced in children than in adults, which is consistent with results reported by Gentaz and Hatwell (1995), who reported a larger oblique effect in adults than in children (aged 7 to 10 years). The authors reported no separate deviations for horizontal and vertical orientations for children and adults, so it cannot be established if this is due to differences between vertical and horizontal deviations in their groups. It is also unclear how the participants in the study of Gentaz and Hatwell (1995) performed the settings in the horizontal orientation. It is possible that they were allowed to direct both hands inwards or outwards, which is mechanically easier to do than directing one hand inwards and the other outwards. In our study participants had to do the latter by pointing the arrows of both bars in the same direction to the right (or left for left-handed participants). Pointing the hands inwards is comparable to mirroring the bars. In studies where participants were asked to mirror the orientations only small deviations have been observed (Fernández-Díaz & Travieso, 2011; Kaas & Van Mier, 2006; Kappers, 2004; Van Mier, 2013). In such a condition, the use of an egocentric

reference frame is actually beneficial, hence the small deviations. However, in these studies participants were explicitly instructed to mirror the bars to each other. The participants in the study of [Gentaz and Hatwell \(1995\)](#) were most likely instructed to parallel the orientations. This instruction is crucial. Paralleling a bar in the vertical orientation of 90° involves the same positioning of the hands and setting of the bars as mirroring this orientation. Nevertheless, deviations for the vertical 90° orientation were much larger when participants were instructed to parallel the bars than when instructed to mirror them ([Fernández-Díaz & Travieso, 2011](#); [Kaas & Van Mier, 2006](#); [Kappers, 2004](#); [Van Mier, 2013](#)) showing a clear effect of task instruction ([Van Mier 2014](#)). So, although the participants in Gentaz and Hatwell's study might have been able to use a mirror setting of their hands when paralleling the horizontal orientation, the task instruction might have resulted in comparable deviations for the vertical and horizontal orientations in their study. Using a mirror setting of the hands, which is mechanically easier, to match the horizontal orientation might have resulted in smaller deviations. Apparently, as the results from the current study illustrate, it is more difficult for children to parallel a horizontal orientation of 0° than an oblique orientation of 45° . If this is due to mechanical aspects, maybe related to the fact that children have smaller hands, could be tested in a follow-up study.

5. Conclusion

The current study showed that previously reported results in adults regarding gender and orientation effects in haptic parallelity matching were replicated in children. It was found that boys performed significantly better than girls while both genders had larger deviations for oblique orientations than cardinal orientations. In addition, it was found that children and adults performed the haptic parallelity task at a comparable level. Although alternative explanations cannot completely be ruled out at the moment, the results suggest that it is most likely that haptic parallelity matching in children in late childhood is driven by the same underlying processes as in adults. Both adults and children seem to use an intermediate reference frame to make two bars haptically parallel to each other, with girls and women being less able to disregard the biasing influence of the hand-centered egocentric reference frame. Future experiments including younger children and adolescents are proposed to reveal if the influence of the egocentric reference frame is similar in younger children and/or if the influence decreases in boys during adolescence. Another venue could be to test if deviations in haptic parallelity matching decrease in girls when the bias of the hand-centered egocentric reference frame is decreased.

Acknowledgements

The author would like to thank Klára Ertl en Sedem Demir for their help in testing the children, and Inge Hansen and Hella Jeurissen for their help in testing part of the adult participants.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

- Annett, M. (2004). Hand Preference Observed in Large Healthy Samples: Classification, Norms and Interpretations of Increased Non-Right-Handedness by the Right Shift Theory. *British Journal of Psychology*, *95*, 339-353. <https://doi.org/10.1348/0007126041528130>
- Baud-Bovy, G., & Gentaz, E. (2012). The Perception and Representation of Orientations: A Study in the Haptic Modality. *Acta Psychologica*, *141*, 24-30. <https://doi.org/10.1016/j.actpsy.2012.06.002>
- Berenbaum, S. A., & Beltz, A. M. (2011). Sexual Differentiation of Human Behavior: Effects of Prenatal and Pubertal Organizational Hormones. *Frontiers in Neuroendocrinology*, *32*, 183-200. <https://doi.org/10.1016/j.yfrne.2011.03.001>
- Davison, K. K., & Susman, E. J. (2001). Are Hormone Levels and Cognitive Ability Related during Early Adolescence? *International Journal of Behavioral Development*, *25*, 416-428. <https://doi.org/10.1080/016502501316934842>
- Fernández-Díaz, M., & Travieso, D. (2011). Performance in Haptic Geometrical Matching Tasks Depends on Movement and Position of the Arm. *Acta Psychologica*, *136*, 382-389. <https://doi.org/10.1016/j.actpsy.2011.01.003>
- Gentaz, E., & Hatwell, Y. (1995). The Haptic 'Oblique Effect' in Children's and Adults' Perception of Orientation. *Perception*, *24*, 631-646. <https://doi.org/10.1068/p240631>
- Gentaz, E., Badan, M., Luyat, M., & Touil, N. (2002). The Manual Haptic Perception of Orientations and the Oblique Effect in Patients with Left Visuo-Spatial Neglect. *Neuroreport*, *13*, 327-331. <https://doi.org/10.1097/00001756-200203040-00016>
- Gentaz, E., Baud-Bovy, G., & Luyat, M. (2008). The Haptic Perception of Spatial Orientations. *Experimental Brain Research*, *187*, Article No. 331. <https://doi.org/10.1007/s00221-008-1382-0>
- Hassler, M. (1991). Maturation Rate and Spatial, Verbal and Musical Abilities: A Seven-Year-Longitudinal Study. *International Journal of Neuroscience*, *58*, 183-198. <https://doi.org/10.3109/00207459108985434>
- Hermens, F., Kappers, A. M. L., & Gielen, S. C. A. M. (2006). The Structure of Frontoparallel Haptic Space Is Task Dependent. *Perception & Psychophysics*, *68*, 62-75. <https://doi.org/10.3758/BF03193656>
- Kaas, A. L., & Van Mier, H. I. (2006). Haptic Spatial Matching in Near Peripersonal Space. *Experimental Brain Research*, *170*, 403-413. <https://doi.org/10.1007/s00221-005-0223-7>
- Kappers, A. M. L. (1999). Large Systematic Deviations in the Haptic Perception of Parallelity. *Perception*, *28*, 1001-1012. <https://doi.org/10.1068/p281001>
- Kappers, A. M. L. (2002). Haptic Perception of Parallelity in the Midsagittal Plane. *Acta Psychologica*, *109*, 25-40. [https://doi.org/10.1016/S0001-6918\(01\)00047-6](https://doi.org/10.1016/S0001-6918(01)00047-6)
- Kappers, A. M. L. (2003). Large Systematic Deviations in a Bimanual Parallelity Task: Further Analysis of Contributing Factors. *Acta Psychologica*, *114*, 131-145. [https://doi.org/10.1016/S0001-6918\(03\)00063-5](https://doi.org/10.1016/S0001-6918(03)00063-5)
- Kappers, A. M. L. (2004). The Contributions of Egocentric and Allocentric Reference Frames in Haptic Spatial Tasks. *Acta Psychologica*, *117*, 333-340.

- <https://doi.org/10.1016/j.actpsy.2004.08.002>
- Kappers, A. M. L. (2007). Haptic Space Processing—Allocentric and Egocentric Reference Frames. *Canadian Journal of Experimental Psychology*, *61*, 208-218.
<https://doi.org/10.1037/cjep2007022>
- Kappers, A. M. L., & Koenderink, J. J. (1999). Haptic Perception of Spatial Relations. *Perception*, *28*, 781-795. <https://doi.org/10.1068/p2930>
- Kappers, A. M. L., & Schakel, W. B. (2011). Comparison of the Haptic and Visual Deviations in a Parallelity Task. *Experimental Brain Research*, *208*, 467-473.
<https://doi.org/10.1007/s00221-010-2500-3>
- Kappers, A. M. L., & Viergever, R. F. (2006). Hand Orientation Is Insufficiently Compensated for in Haptic Spatial Perception. *Experimental Brain Research*, *173*, 407-414.
<https://doi.org/10.1007/s00221-006-0377-y>
- Kappers, A. M. L., Postma, A., & Viergever, R. F. (2008). How Robust Are the Deviations in Haptic Parallelity? *Acta Psychologica*, *128*, 15-24.
<https://doi.org/10.1016/j.actpsy.2007.09.006>
- Lechelt, E. C., & Verenka, A. (1980). Spatial Anisotropy in Intramodal and Cross Modal Judgements of Stimulus Orientations: The Stability of the Oblique Effect. *Perception*, *9*, 581-589. <https://doi.org/10.1068/p090581>
- Liben, L. S., Susman, E. J., Finkelstein, J. W., Chinchilli, V. M., Kunselman, S., Schwab, J., Semon Dubas, J., Demers, L. M., Lookingbill, G., D'Arcangelo, M. R., Krogh, H. R., & Kulin, H. E. (2002). The Effects of Sex Steroids on Spatial Performance: A Review and an Experimental Clinical Investigation. *Developmental Psychology*, *38*, 236-253.
<https://doi.org/10.1037/0012-1649.38.2.236>
- Luyat, M., & Gentaz, E. (2002). Body Tilt Effect on the Reproduction of Orientations: Studies on the Visual Oblique Effect and Subjective Orientations. *Journal of Experimental Psychology: Human Perception and Performance*, *28*, 1002-1011.
<https://doi.org/10.1037/0096-1523.28.4.1002>
- Raven, J. C., Court, J. H., & Raven, J. (1992). *Manual for Raven's Progressive Matrices and Vocabulary Scales*. Oxford Psychologists Press.
- Spencer, J. P., Simmering, V. R., & Schutte, A. R. (2006). Toward A Formal Theory of Flexible Spatial Behavior: Geometric Category Biases Generalize Across Pointing and Verbal Response Types. *Journal of Experimental Psychology: Human Perception and Performance*, *32*, 473-490. <https://doi.org/10.1037/0096-1523.32.2.473>
- Van Mier, H. I. (2013). Effects of Visual Information Regarding Allocentric Processing in Haptic Parallelity Matching. *Acta Psychologica*, *144*, 352-360.
<https://doi.org/10.1016/j.actpsy.2013.07.003>
- Van Mier, H. I. (2014). Haptic Perception of Parallelity. *Psychology and Behavioral Sciences*, *3*, 212-221. <https://doi.org/10.11648/j.pbs.20140306.16>
- Van Mier, H. I. (2016). Reducing the Motor Response in Haptic Parallel Matching Eliminates the Typically Observed Gender Difference. *Experimental Brain Research*, *234*, 105-115.
<https://doi.org/10.1007/s00221-015-4437-z>
- Van Mier, H. I. (2019). Changing the Influence of the Egocentric Reference Frame Impacts Deviations in Haptic Parallelity Matching. *Experimental Brain Research*, *237*, 2387-2395. <https://doi.org/10.1007/s00221-019-05596-x>
- Van Mier, H. I. (2020). Combining Visual and Haptic Practice Significantly Reduced Deviations in Haptic Parallelity Matching. *Acta Psychologica*, *203*, Article ID: 103008.
<https://doi.org/10.1016/j.actpsy.2020.103008>
- Van Mier, H. I. (2021). Gender Differences in Haptic Parallelity Matching. *Psychology*,

12, 607-623. <https://doi.org/10.4236/psych.2021.124038>

Van Mier, H. I., & Jiao, H. (2020). Influence of Action Video Gaming on Spatial Representation in the Haptic Modality. *Experimental Brain Research*, 238, 2769-2781.

<https://doi.org/10.1007/s00221-020-05931-7>

Volcic, R., Kappers, A. M. L., & Koenderink, J. J. (2007). Haptic Parallelity Perception on the Frontoparallel Plane: The Involvement of Reference Frames. *Perception & Psychophysics*, 69, 276-286. <https://doi.org/10.3758/BF03193749>

Volcic, R., Van Rheede, J. J., Postma, A., & Kappers, A. M. L. (2008). Differential Effects of Non-Informative Vision and Visual Interference on Haptic Spatial Processing. *Experimental Brain Research*, 190, Article No. 31.

<https://doi.org/10.1007/s00221-008-1447-0>

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of Sex Differences in Spatial Abilities: A Meta-Analysis and Consideration of Critical Variables. *Psychological Bulletin*, 117, 250-270. <https://doi.org/10.1037/0033-2909.117.2.250>

Zuidhoek, S., Kappers, A. M. L., & Postma, A. (2007). Haptic Orientation Perception: Sex Differences and Lateralization of Functions. *Neuropsychologia*, 45, 332-341.

<https://doi.org/10.1016/j.neuropsychologia.2006.05.032>

Zuidhoek, S., Kappers, A. M. L., Van Der Lubbe, R. H. J., & Postma, A. (2003). Delay Improves Performance on a Haptic Spatial Matching Task. *Experimental Brain Research*, 149, 320-330. <https://doi.org/10.1007/s00221-002-1365-5>