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ORIGINAL ARTICLE

Sex differences in parking are affected by biological and social factors

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Abstract The stereotype of women's limited parking skills is deeply anchored in modern culture. Although laboratory tests prove men's average superiority in visuospatial tasks and parking requires complex, spatial skills, underlying mechanisms remain unexplored. Here, we investigated performance of beginners (nine women, eight men) and more experienced drivers (21 women, 27 men) at different parking manoeuvres. Furthermore, subjects conducted the mental rotation test and self-assessed their parking skills. We show that men park more accurately and especially faster than women. Performance is related to mental rotation skills and self-assessment in beginners, but only to self-assessment in more experienced drivers. We assume that, due to differential feedback, self-assessment incrementally replaces the controlling influence of mental rotation, as parking is trained with increasing experience. Results suggest that sex differences in spatial cognition persist in real-life situations, but that socio-psychological factors modulate the biological causes of sex differences.

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Introduction

Numerous psychological studies prove the existence of sex differences in certain cognitive abilities (Halpern 2000; Kimura 1999; Kimura 2002). Although performances of the sexes overlap to a large degree, women tend to outperform men in some aspects of verbal cognition such as phonological retrieval in the letter fluency task (Crossley, D'Arcy, Rawson 1997; Hines 1990), and verbal memory (Chipman & Kimura 1998; Kramer, Delis, Daniel 1988). Men, on the other hand, obtain higher average scores in some spatial tasks, with largest and most stable differences being found for the Mental Rotation Test (Linn & Petersen 1985; Masters & Sanders 1993; Voyer, Voyer, Bryden 1995). In the typically applied paper–pencil version of this test (Peters et al. 1995; Vandenberg & Kuse 1978), subjects must identify similar versions of abstract 3-D cube-figure drawings (Shepard & Metzler 1971), which are shown from different perspectives. Women and men seem to use different strategies when solving the task, with men tending to use visual–spatial, and women verbal or analytical strategies (Bethell-Fox & Shepard 1988; Pezaris & Casey 1991; Schultz 1991). As for other spatial abilities, mental rotation skills are subject to training effects, with repeated training increasing performance (Lohmann & Nichols 1990; Peters et al. 1995; Wright, Thompson, Ganis, Newcombe, Kosslyn 2008).

Although it is the common goal of researchers to understand human cognition as it occurs under natural circumstances, most theories about sex differences in cognitive abilities—including mental rotation skills—have been established from results obtained in controlled, standardised, and artificial laboratory environments. Human cognition, however, is context-dependent (Kingstone, Smilek, Eastwood 2008). Thus, the transferability of theories about cognitive sex differences to real life is not necessarily given. It is therefore remarkable that mental rotation skills have rarely been investigated in real life or at least virtual reality (Vidal, Lehman, Bülthoff 2009; Wang & Simons 1999), although they are among the most often cited abilities in the context of cognitive sex differences. The limited number of studies focusing on human cognition in complex real-life situations is problematical, as reports on cognitive sex differences have found their way into the mass media, and millions of dollars have been spent on pseudo-scientific books addressing alleged differences between women and men (Halpern 1996). It is therefore likely that certain sex stereotypes found in modern society are caused and boosted by scientific reports. Women, for instance, are assumed to be more talkative than men. This difference is commonly thought to be a biologically based, evolved adaptation in order to handle communication and relationships (Brizendine 2006). Recording of natural language while participants went about their daily lives, however, revealed large individual but no sex differences in word use (Mehl et al. 2007).

According to a probably even more widespread stereotype, women's parking skills are not as good as men's. To date, however, the validity of this stereotype has never been examined with scientific methods, and the cognitive mechanisms involved in parking have never been investigated. During everyday life—and obviously especially during parking—individuals are required to imagine themselves from different perspectives, which involves mental rotation (Vidal et al. 2009). A driver who steers towards a parking space must predict the outcome of spatial relationships between objects (including own car, parking space, further cars, and kerb) after changes in viewpoint, which arise from the car's—and thus the driver's—motion. Consequently, people with superior mental rotation skills could be the better parkers. Real-life cognition and behaviour, however, is the result of both biological and environmental factors (Halpern 2000; Halpern & Tan 2001; Hausmann, Schoofs, Rosenthal, Jordan 2009). It would therefore be simplistic to assume that parking performance depends exclusively on spatial skills. A powerful environmental factor that determines behaviour and achievement of an individual is the belief in the own skills. This belief is mainly influenced by the interpretation of the results of the own performance, and it can be depressed by stress and anxiety (Bandura 2003; Pajares 1996; Schunk & Swartz 1993). Belief in one's skills is domain-specific, with men reporting higher levels for some domains, and women for others (Gentile et al. 2009). It is thus possible that parking performance depends not only on spatial skills, but also on assessment of the own capabilities in the domain "driving and parking".

We therefore investigated the relationship between mental rotation skills and self-assessment, respectively, and parking performance. Male and female driving beginners as well as more experienced drivers conducted a paper–pencil test for mental rotation, self-assessed their parking skills in a questionnaire, and carried out different types of parking manoeuvres. Thus, we aimed to unravel the cognitive mechanisms involved in parking, as well as possible changes of these mechanisms over time, as driving experience increases.

Method

Subjects

A total of 65 subjects (30 women, 35 men) participated in the study. Seventeen subjects (nine women, eight men) were driving beginners, who had their driver's licence no longer than 2 weeks. The remaining 48 subjects (21 women, 27 men) were more experienced. Criterion for participation for the more experienced drivers was that they had never owned a car and had not driven regularly since acquisition of the driver's licence (not more than twice a week for a time period of more than 3 months in succession). No age differences between women and men were present in the overall group (women 20.9 years, SD = 3.3; men 22.3 years, SD = 3.3; $t(63) = -1.66$, $p = 0.63$), as well as in the beginners group (women 18.3 years, SD = 2.4; men 18.5 years, SD = 0.8; $t(15) = -0.18$, $p = 0.85$) and the group consisting of more experienced drivers (women 22.0 years, SD = 3.0; men 23.5 years, SD = 2.9; $t(46) = -1.59$, $p = 0.12$). Intelligence quotient (IQ) was determined with the multiple choice intelligence test version B (Lehrl 1977), a test routinely used in Germany. IQ neither differ between women and men in the overall group (women 101.0, SD = 9.6; men 100.9, SD = 7.4; $t(63) = 0.08$, $p = 0.93$) nor in beginners (women 96.0, SD = 3.7; men 98.5, SD = 5.3; $t(15) = -1.30$, $p = 0.27$) or more experienced drivers (women 103.2, SD = 10.6; men 101.6, SD = 7.8; $t(46) = 0.63$, $p = 0.54$). Subjects were neurologically healthy, had normal or corrected visual acuity, were naïve of the experimental hypothesis, and were paid for participation. Furthermore, they gave written informed consent and were treated in accordance with the declaration of Helsinki. The study had been approved by the ethics committee of the Ruhr-University Bochum.

Parking manoeuvres

Because Galea and Kimura (1993) found that men drive more frequently than women, a detailed questionnaire was applied in which subjects specified their driving and parking experience. More experienced drivers were asked for years since acquisition of the driver's licence. Furthermore, frequencies of both driving and parking were indicated by beginners and more experienced drivers on a 5-point scale ranging from −2 (very infrequently) to +2 (very often). Parking manoeuvres were conducted with an Audi A6 Limousine Automatic, provided by the Audi AG Ingolstadt, in an area of a multi-storey car park that had been closed off for the public. Two parking spaces for three types of manoeuvres were provided: one for forward and backward bay, and one for reverse parallel parking. Each parking space was marked with white adhesive tape and measured 4.9 × 1.8 m, which corresponded to the size of the Audi. Parking spaces were restricted by junk cars. The distance between two junk cars restricting the bay parking space was 3.6 m (two times the width of the Audi). The rear side of the parking space was bordered by the wall of the parking garage, located at a distance of 30 cm. The distance between the cars restricting the parallel parking space was 7.35 m (one and a half times the length of the Audi). Here, the bordering wall was located at a distance of 70 cm.

Starting positions for the different types of parking manoeuvres (Figs. 1, 2) were specified by connecting the centre of each position (corresponding to the centre of the Audi when standing at the starting position) with the centre of the parking space in a right angle. Thus, measurements formed the *x*- and *y*-axis of a two-dimensional coordinate system. For forward left and right bay parking, starting positions were located at a distance of 13.2 m (*x*-axis) and 6.7 m (*y*-axis) of the parking space. Starting positions for backward left and right bay parking were located at a distance of 8.2 m (*x*-axis) and 4 m (*y*-axis). Bay parking manoeuvres were filmed from a distance of 13 m from the centre of the parking space. Starting positions for reverse parallel parking were located at a distance of 6.4 m (*x*-axis) and 2.8 m (*y*-axis) of the parking space. The distance between the camera and centre of the parking space was

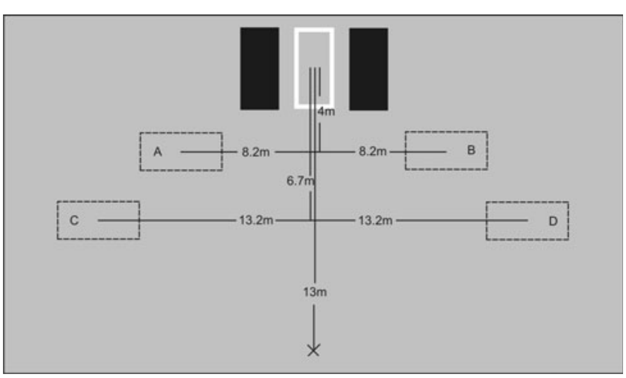

Fig. 1 Starting positions for bay parking. Subjects parked four times from predetermined starting positions (*rectangles in dashed lines*). *A* backward bay parking right, *B* backward bay parking left, *C* forward bay parking left, *D* forward bay parking right. *Black cross* camera

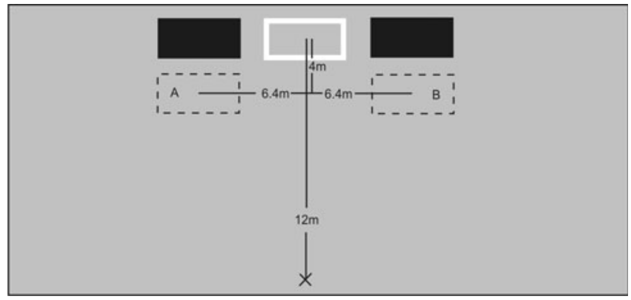

Fig. 2 Starting positions for parallel parking. Subjects parked two times from predetermined starting positions (*rectangles in dashed lines*). *A* parallel parking right, *B* parallel parking left. *Black cross* camera

12 m. Appropriate starting positions had been determined in preliminary tests in a way that, from each position, it was theoretically possible to park the car without having to back up.

First, subjects were made familiar with the Audi. They were asked to sit on the driver's seat and to adjust the seat, the rear and side view mirrors. In Germany, driving schools generally use cars with manual transmission, which also are used by the majority of the German population. Thus, subjects were instructed how to drive an automatic car. After potential questions had been answered, a test drive was conducted. Subjects drove a distance of approximately 35 m, backed up, and drove back the same distance. Then, they backed up again and manoeuvred the car to the same position as in the beginning. Thereupon, subjects had a closer look at the parking spaces. They were told to park in the middle between and in line with the junk cars. Furthermore, they were instructed to have a closer look at the Audi, especially at the length of rear end and hood. It was pointed out that no advice would be given by the experimenter, and that the engine must be turned off after a manoeuvre had been completed. Importantly, subjects were not allowed to modify starting positions (for instance by driving further away from the parking space). Rather, they were told to drive towards the parking space directly from the predetermined position. Nevertheless, subjects could back up as often as necessary later. All subjects bay parked forward, bay parked backward, and reverse parallel parked once from the left and once from the right side. Thus, each subject conducted six manoeuvres in total. The order of manoeuvres was pseudo-randomised across subjects. Prior to the beginning of each parking manoeuvre, the experimenter drove the car into the starting position and subjects were informed which manoeuvre to conduct next. Parking duration and accuracy were recorded. Parking duration was defined as time in seconds between first movement of the car and turning off the engine. Accuracy was defined as area in percent of the parking space that was covered by the Audi, and was calculated based on the distance of the car from the boundaries of the parking marked parking space using Matlab 7.0.4 (The MathWorks Inc., Natick, MA, USA). For data analysis, parking duration and accuracy of left and right manoeuvres of the same type were pooled.

Self-assessment and mental rotation test

Directly after parking manoeuvres had been completed, subjects were given a questionnaire in which they were asked to assess their general driving and parking skills ("general self-assessment"; including the questions: "how much do you like driving?", "are you rather bold or shy when driving?", "how good, in general, do you drive?", and "how good, in general, do you park?"), and their performance during the experiment ("actual self-assessment"; including the questions: "how good, do you think, did you park during the experiment?", and "do you assess your performance during the experiment being better or worse compared to your general parking skills?"). Participants were asked to indicate their performance level for each question on a 5-point scale ranging from −2 (indicating negative self-assessment) to +2 (indicating positive self-assessment).

Furthermore, subjects were tested with the redrawn version of the paper–pencil mental rotation test (Peters et al. 1995), in which they had to identify rotated versions of 3-D cube figures. The test consisted of 24 items (two subsets of 12 items each). In each case, the stimulus on the left was the target. Subjects had to determine, which two of the four sample stimuli on the right side of the target were rotated versions of the target stimulus. Subjects had three minutes for each subset of 12 items, which were conducted directly after each other. A score of "1" per item was given, if both rotated versions of the target had been identified correctly. A score of "0" was given, if only one of none of the rotated stimuli had been identified. Thus, the maximum overall score was 24.

Results

Men and women did not differ in driving and parking experience. They did not differ in years since they held the driver's licence (women 4.0 years, SD = 2.5; men 4.9 years, SD = 2.0; $t(46) = -1.3$, $p = 0.87$). Furthermore, no sex difference in driving frequency was present in the overall group (women −0.7, SD = 1.2; men −1.0, SD = 1.1, $t(58) = 0.89$, $p = 0.38$), as well as in the beginners group (women 0.4, SD = 1.3; men −0.5, SD = 1.5; $t(12) = 1.61$, $p = 0.27$), and the group consisting of subjects with more experience (women −1.2, SD = 0.8; men −1.1, SD = 1.0; $t(44) = -0.30$, $p = 0.77$). As for driving frequency, no differences were found for parking frequency. Again, this was the case for the overall group (women −0.5, SD = 0.7; men −0.3, SD = 0.7; $t(59) = -1.18$, $p = 0.24$), as well as for beginners (women −0.5, SD = 0.4; men −0.8, SD = 0.7; $t(12) = 0.88$, $p = 0.39$), and more experienced drivers (women −0.5, SD = 0.8; men −0.1, SD = 0.6, $t(45) = -1.82$, $p = 0.08$).

A 3 × 2 × 2 repeated measures ANOVA with type of parking manoeuvre (left and right manoeuvres were pooled) as within-subjects factor and driving experience and sex as between-subjects factors revealed that parking duration was shortest when bay parking forward and longest when parallel parking ($F_{(2,120)} = 25.10$, $p = 0.00$). Beginners' parking duration was longer those of more experienced drivers ($F_{(1,60)} = 6.61$, $p = 0.01$; Cohen's $d = 0.68$; $\eta^2 = 0.10$). Furthermore, women's parking duration was longer compared to those of men (Fig. 3a; $F_{(1,62)} = 26.73$, $p = 0.00$; Cohen's $d = 1.33$; $\eta^2 = 0.31$) in all types of manoeuvres (Bonferroni-corrected post-hoc tests; all $p = 0.00$). No significant interactions between parking manoeuvre, experience, and sex were found (all $F < 1.58$; all $p > 0.21$). In contrast to parking duration, no differences in parking accuracy were present between the types of manoeuvres ($F(2,122) = 1.15$, $p = 0.32$). Comparable to the results for parking duration, driving beginners parked less accurate than more experienced drivers ($F(1,61) = 9.66$, $p = 0.03$; Cohen's $d = 0.81$; $\eta^2 = 0.14$) and women less accurate than men (Fig. 3b; $F(1,61) = 7.76$; $p = 0.01$; Cohen's $d = 0.58$; $\eta^2 = 0.11$). However, when tested separately for the three different types of manoeuvres, the sex difference in parking accuracy reached significance only for parallel parking (Bonferroni-corrected post hoc test; $p = 0.04$), but not for forward ($p = 0.22$) or backward ($p = 0.14$) bay parking. No significant interactions were found (all $F < 2.785$; all $p > 0.100$).

To investigate whether subjects showed speed-accuracy trade-offs (Zhai, Kong, Ren 2004) when parking, all manoeuvres were pooled and duration was plotted against accuracy (Fig. 4). Also, Pearson correlation coefficients (one-tailed) between duration and accuracy were calculated. For men, there was no relation between the two variables ($r = -0.04$; $p = 0.81$), whereas women were more accurate when parking duration was shorter ($r = -0.44$; $p = 0.01$). Thus, no speed-accuracy trade-offs were present in the data.

Women gave themselves lower general ($t(63) = -3.71$; $p = 0.00$) but not actual ($t(63) = 0.70$; $p = 0.49$) parking skill ratings than men. These two measures were not correlated (two-tailed Pearson correlation $r = 0.08$; $p = 0.53$), indicating that subjects differentiated between their performance in the experiment and their general parking ability. In accordance with literature, men outperformed women in the mental rotation test ($t(61) = -2.15$; $p = 0.04$). To determine the influence of mental rotation skills and self-assessment

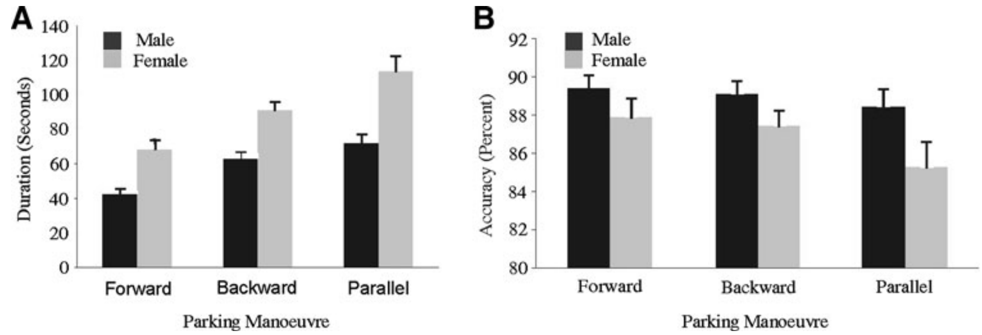

Fig. 3 Parking duration (*A*) and accuracy (*B*) for men (*black* $N = 35$) and women (*grey* $N = 30$) for forward bay, backward bay and reverse parallel parking. Manoeuvres of the same type that had been conducted from the left and right were pooled. *Error bars* show standard error means

on parking performance, one-sided Pearson correlation coefficients were calculated. In the overall sample consisting of beginners and more experienced subjects, parking duration ($r = -0.41$, $p = 0.00$) and accuracy ($r = 0.26$, $p = 0.02$) correlated significantly with general self-assessment. However, correlations between mental rotation ability and parking duration ($r = -0.13$, $p = 0.17$) as well as accuracy ($r = 0.19$, $p = 0.07$) did not reach significance. In driving beginners, parking duration ($r = -0.51$, $p = 0.02$), but not accuracy ($r = 0.30$, $p = 0.13$), was significantly related to mental rotation skills. In contrast, parking accuracy ($r = 0.49$, $p = 0.02$), but not duration ($r = -0.37$, $p = 0.08$), was significantly related self-assessment. In more experienced subjects, parking duration ($r = -0.58$, $p = 0.00$) as well as accuracy ($r = 0.40$, $p = 0.00$) strongly correlated with self-assessment, whereas not significant correlations were found between duration and mental rotation ability ($r = 0.08$, $p = 0.30$) as well as accuracy and mental rotation ability ($r = 0.09$, $p = 0.27$).

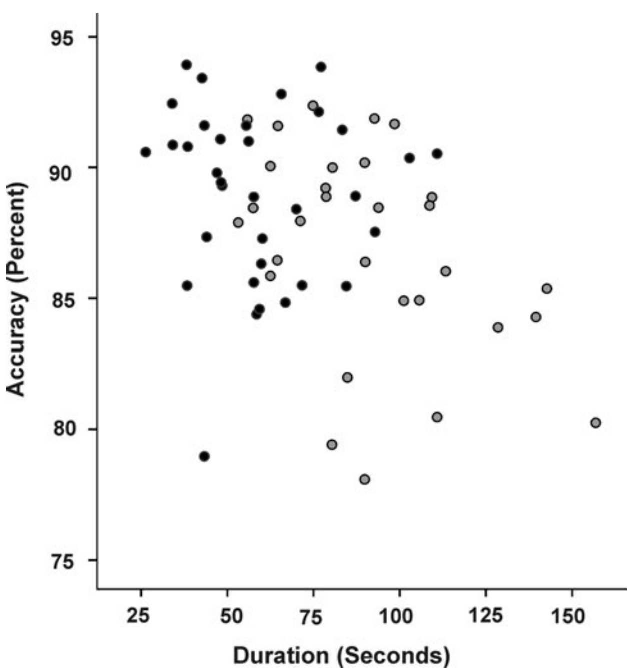

Fig. 4 Plot of parking duration against accuracy for all types of manoeuvres and all subjects. Women (*grey*) were more accurate when duration was shorter ($r = -0.44$; $p = 0.01$), whereas no relation between the variables was found for men (*black*; $r = -0.04$; $p = 0.81$)

Discussion

The present data revealed a sex difference in parking performance in driving beginners as well as in more experienced drivers. Across all three types of manoeuvres, men were 2.4% (range 1.7–3.7%) more accurate, and 35% (range 30.4–37.3%) faster than women. This result is reflected by the effect sizes, because a very large effect ($d = 1.33$) was found for the difference in parking duration, and a medium one for the difference in accuracy ($d = 0.58$). Furthermore, η^2 indicated that 31% of variance in parking duration and 11% in accuracy was accounted for by sex. Different from the findings of Galea and Kimura (1993), driving and parking experience were the same for women and men. Thus, the differences in parking can possibly not be ascribed to a sex difference in previous experience, although ratings about driving and parking frequencies are subjective and should therefore be treated cautiously. In principle, the marked difference in parking duration could be explained in terms of general driving habits. Several studies prove that men take greater driving risks and are prone to disregard of security precautions and involvement in accidents (Bergdahl 2005; Roosenbloom, Ben-Eliyahu, Nemrodov, Biegel, Perlman 2009; Williams 2003). Furthermore, a meta-analysis revealed that men show risky behaviour in a variety of domains (Bymes, Miller, Schafer 1999). However, a sex difference in risk-assessment leading to women parking more cautiously and thus more slowly does not explain why women's final parking position was less accurate than men's, especially for parallel parking. Slower driving should lead to a better and not worse result, as more time for completion of a manoeuvre is available. Obviously, different driving habits cannot explain the observed sex-difference in parking sufficiently.

The correlation coefficients between parking parameters (duration, accuracy) and mental rotation or self-assessment hint at an involvement of both biological and social factors. Correlations, however, do not necessarily imply causal relations and should be interpreted cautiously; but since the coefficients in the present study were considerably large one can at least speculate about the underlying mechanisms of parking ability.

As parking duration was significantly related to performance in the mental rotation test in driving beginners, and men achieved higher scores, differences in mental rotation skills are a possible mechanism underlying the observed sex difference in parking duration. In real life, mental rotation involves the ability to imagine the outcome of spatial relations arising from the motion of the observer himself as well as the imagination of objects being rotated in space (Vidal et al. 2009; Wang & Simons 1999). Presumably, required mental rotation processes are especially complex during parking, as the driver must represent not only his own, but also the vehicle's motion. For subjects, forward bay parking was easiest, followed by backward bay and reverse parallel parking. This result is logical, as backward, and especially parallel parking, involves complex movements of the car, and the direction of car movement is opposite to the driver's orientation. The latter increases the necessity to use rear- and side view mirrors for visualising the surrounding area, which requires additional mental rotation processes.

Interestingly, however, only the correlation between mental rotation and beginners' parking duration reached significance, but not that between mental rotation and accuracy. Rather, self-assessment had explanatory value. Furthermore, self-assessment rather than mental rotation skills were strongly related to overall parking performance of more experienced drivers. How can this shift in the relative contribution of underlying variables be explained? Motor performance improves with practice. After numerous repetitions, movements, which initially are slow, variable, uncoordinated, and fractionated, become fast, stereotyped, coordinated, and smooth (Nudo 2008). This improvement is accompanied by a change in the neural mechanisms involved (Bloedel, Ebner, Wise 1996; Costa 2007; Nudo 2008). As more experienced drivers outperformed beginners, it is possible that repeated training led to an automated skill that depends less on visuospatial skills. As a result, the relation between parking performance and mental rotation could have been reduced. This interpretation is in line with Fleishman and Rich's (1963) finding that the relative contribution of abilities affecting performance at a complex motor task changes as practice continues, and that visuospatial skills are critical only during early stages of learning. Wanzel et al. (2003) investigated the relation between visuospatial skills and performance at a spatially complex surgical task across three levels of expertise, and found that the dependence upon spatial skills declines at an early stage of practice: Mental rotation ability correlated with skilled surgical performance only in novices, who were naïve with respect to performance of the surgery, but not in advanced trainees and experts. These observations would also explain, why driving beginners' parking performance was only partially related to mental rotation skills. The beginners were not completely naïve, but had trained parking repeatedly during driving lessons.

Additionally, unequal base levels of parking performance—which could be due to unequal spatial skills in unexperienced drivers—may have resulted in differential feedback during training of parking skills, leading to a change in self-assessment and thus differential behaviour and achievement (Bandura 2003; Pajares 1996; Schunk & Swartz 1993). It is possible that this especially affects women in the context of driving, as women were found to report lower levels of confidence in their driving skills (D'Ambrosio, Donorfio, Coughlin, Mohyde, Meyer 2008). In a recent driving simulator study, it was found that women, whose self-concept was manipulated by confronting them with the stereotype that females are poor drivers, were twice as likely to collide with pedestrians as women who were not reminded of this stereotype (Yeung & von Hippel 2008).

Taken together, differences in self-assessment and mental rotation skills seem to contribute to an average sex difference in parking performance. Although there is an overlap between the performances of the sexes and average differences do not allow any conclusions about a single individual, a differential base level in mental rotation ability could affect parking skills in a sex-specific way. As parking is trained, women and men would accumulate an unequal history of failures and achievements, resulting in differences in self-assessment and a gender-specific expectation of future success. In this respect, an analysis of parking abilities is able to uncover how possibly biologically rooted sex differences in spatial cognition could develop into differences between groups that are modulated by socio-psychological factors.

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