MOTOR SKILL ACQUISITION INFLUENCES LEARNERS' VISUAL PERCEPTION IN GYMNASTICS

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Abstract

Research has shown that perceiving and predicting the actions of others differs as a function of motor expertise. The aim of this study was to address the question if participants who successfully acquired a handspring over a vaulting box exhibit changes in predicting handspring performances of other people. It was hypothesized that participants who successfully acquired the handspring over a vaulting box should outperform participants of a control group in predicting the landing positions of handspring performances in a computer-based perception test. Participants of an experimental group learned the handspring over a vaulting box following a methodical progression. No treatment was given to the participants of a control group. Landing position predictions were evaluated in a computer-based visual perception test prior to, and at the end of the methodical progression. Results revealed that the participants of the experimental group predicted landing positions more precisely in the posttest compared to the pretest. Furthermore, participants predicted landing positions more precisely when video sequences were occluded earlier, arguing in favor of an optimal information density when predicting landing positions in handsprings. It is stated, that as a learner acquires a motor skill in gymnastics, this changes the way the learner perceives that skill.

Keywords: *handspring, methodical progression, motor expertise.*

INTRODUCTION

Perceiving and predicting the actions of other people is an important skill for coaches, judges, and athletes in the sports domain (Heinen, Vinken & Velentzas, 2012; Williams, 2002). Especially in gymnastics, athletes reported the improvement of skill performance as a main reason for observing skill execution (Hars & Calmels, 2007). It was furthermore demonstrated, that gymnasts benefit from observational learning when acquiring complex skills (Baudry, Leroy & Chollet, 2006). Research has shown that visual perceptual processes are not equal among participants with different levels of motor expertise, but rather differ as a function of this expertise (Blake & Shiffrar, 2007; Williams, 2002). One may speculate if the aforementioned statement may be generalized to gymnastics. The aim of this study was therefore to address the question, if participants who learned a novel motor skill exhibited predictable changes in visual perceptual processes when observing the acquired motor skill?

Empirical evidence suggests that experts were better at picking up advance cue information in visual perception tasks (Savelsbergh, Williams, van der Kamp & Ward, 2002; Williams, Davids & Williams, 1999). For example, researchers utilized the temporal occlusion paradigm in which participants were presented video sequences that were selectively edited on their duration, and thus showed different occlusion windows (Mann, Abernethy, Farrow, Davis & Spratford, 2010). The perspective of the video sequences usually represented the participants' view of action when being engaged in the corresponding activity (Farrow & Abernethy, 2003). However, other perspectives such as the perspective of an external observer were used in temporal occlusion studies (Knoblich & Flach, 2001; Loula, Prasad, Harber & Shiffrar, 2005). Participants were required to predict some movement result such as the corner of a goal during a penalty kick or the landing position of a dart on a dartboard. Aglioti, Cesar, Romani, and Urgesi (2008) had expert basketball players predict the success of basketball free throws. Therefore, participants watched video clips of a professional basketball player performing free throws. The video clips were presented with different occlusion windows before the ball either landed in or out of the basket. Athletes exhibited more correct responses under earlier occlusion conditions when predicting the ball in or out of the basket, as compared to participants with comparable visual experience such as coaches or sports journalists, and novices. From the results the authors concluded that motor expertise is of high importance in the perception of motor actions (Aglioti et al., 2008).

The ability to perceive the actions of other people thus seems to stem at least in part from the amount of experience one has gained in observing, planning and executing these actions, because experts are attuned to the most important perceptual information (Raab, de Oliveira & Heinen, 2009; Ward, Williams & Bennett, 2002). There is further evidence that observers' own action system significantly contributes to the visual perception of human movement (Prinz, 1997). Thus, an actor should be more sensitive to the perception of actions that the actor is able to execute by himself than to actions that the actor is unable to execute. To test this hypothesis, Knoblich and Flach (2001) asked participants to predict the landing positions of dart throws at a target board after watching video clips displaying either himself or herself or somebody else throwing the dart. The video clip ended right before the dart left the participants' hand. It was found that the predictions were more accurate when participants watched themselves acting. It could furthermore be shown, that people were able to improve their movement perception when practicing particular movements blindfolded (Casile & Giese, 2006).

Taken together, there is converging evidence, that motor skill acquisition has a direct and highly selective influence on visual action recognition that is not mediated by visual learning alone (Blake & Shiffrar, 2007). However, to the best of our knowledge, there is no study in the field of gymnastics evaluating the latter hypothesis in participants who learned a novel motor skill. Thus in the current study students learned a novel motor skill, namely the handspring performed over a vaulting box. Participants' predictions of handspring landing positions were evaluated in a computer-based visual perception test (see Method section for details). Because participants' motor system is thought to influence visual perceptual processes, it was first hypothesized, that participants who successfully acquired the handspring would outperform participants of a control group in the visual perception test. The second hypothesis was, that participants who learned the handspring should also exhibit better prediction accuracy under earlier occlusion windows compared to participants of a control group.

METHODS

Students of Sport Science (*N* = 36, age: 23 ± 2 years) were recruited to participate in this study. The number of participants was derived from a power analysis when expecting a medium effect (Cohen's *f* > 0.25, type I error probability 5%, type II error probability 20%). The participants had no particular experience in gymnastics at the beginning of the study. All participants were asked to participate in a study on motor learning and perceptual processes in gymnastics. They were informed about the procedure of the study and gave their written consent prior to the study. Participants (*n* = 18) were randomly assigned to a control group and the remaining participants (*n* = 18) were assigned to an experimental group. The participants of the experimental group were supposed to learn the handspring on vault by means of a methodical progression, whereas the participants of the control group were neither present during the practice sessions nor were engaged in any gymnastic activity. The participants of both, the control and the experimental group were asked to evaluate landing positions of handspring performances in a computer-based visual perception test prior to the methodical progression and at the end of the methodical progression. All participants of the experimental group completed the methodical progression and achieved the handspring. There were no injuries during the experiment.

Experimental task and methodical progression. The experimental task was to learn a handspring on vault. The handspring had to be performed over a vaulting box with the help of a miniature trampoline. The vaulting box was adjusted to a height of 1.10 m, which matched the examination guidelines of the universities' curriculum in the field of 'gymnastics and movement arts'.

The methodical progression was derived from the universities' curriculum in the field of 'gymnastics and movement arts' and consisted of five distinct tasks: (1) swing to handstand on the floor and falling over in a supine position onto a gymnastics mat, (2) jumping to handstand on a vaulting box (height: 1.00 m) from a miniature trampoline and falling over in a supine position onto a stack of gymnastics mats (height: 1.00 m), (3) swinging to handstand on a base of two vaulting boxes and falling over to stand with manual assistance, (4) performing the handspring over a vaulting box with manual assistance during the first flight phase and second flight phase, and (5) performing the handspring over the vaulting box without any further guidance.

Different key instructions were systematically integrated in the methodical progression. The key instructions were: (1) "keep a rigid body and keep your hips and shoulders open" (all steps of the methodical progression), (2) "accelerate back leg/legs to handstand position" (all steps of the methodical progression), (3) "actively push with your arms, enabling you to spring off the take-off surface" (steps 3, 4, and 5), (4) "anticipate floor and actively absorb your energy when landing" (steps 4, and 5), and (5) "perform accelerated, yet controlled run-up" (step 4, and 5). Verbal feedback was provided as summary feedback on the movement quality of three to five observed attempts (Schmidt & Lee, 2005). Task-specific lead-up activities, such as performing a handstand on the floor with manual assistance or running towards the trampoline and performing a straight jump were additionally integrated in the progression (Turoff, 1991). Manual assistance was systematically integrated into the methodical progression and provided when necessary.

Preparation of video sequences. Video sequences for the computer-based perception test were generated on the basis of handspring performances of another six students of Sport Science who were not part of the study sample. The six students had at least two years of experience in performing handsprings over a vaulting box due to their successful participation in the universities' gymnastics courses. It was decided to recruit students of Sport Science for the preparation of the video sequences because they were most congruent to the sample of our study in terms of their perceptual-motor capabilities and the structure of their motor system, which is thought to be an important precondition when experimentally assessing visual perception related to motor expertise (Blake & Shiffrar, 2007). The six students were asked to perform the handspring on the vaulting box eight times while trying to land in an upright posture according to the judging guidelines (FIG, 2009). This resulted in a total of 48 video sequences. The performances were videotaped with a full HD digital video camera operating at 50 Hz (spatial resolution: 1920 x 1080 pixels). The camera was placed at a distance of 15 m from the vaulting box and orthogonal to the movement direction of the students.

From the eight video sequences of each student, the performances with the best quality and with a stuck landing were selected with the help of one gymnastic coach with national experience. The coach could use a laptop computer to play back the video sequences in slow motion whenever needed. From this, 18 video sequences had to be removed from the experiment, because neither the landing was stuck, nor the quality of the handsprings was rated as sufficient by the coach. In the next step, the absolute landing positions of the remaining 30 video sequences were analyzed for an equal distribution in landing positions. Since the precondition of an equal distribution in absolute landing positions was violated, the amount of video sequences was systematically varied, until two conditions were fulfilled: 1. the absolute landing positions of the handsprings were distributed equally over the landing mat and 2. the amount of handspring sequences was equal among the students. This procedure resulted in three valid handspring performances for each student, leading to a total of 18 handspring performances.

Each of the 18 handspring sequences was cut into three further sequences, with each of the three sequences representing one of three Occlusion Windows (Figure 1): (1) t1 = occlusion began at first video frame after take-off from the vaulting box, (2) t2 = occlusion began after the video frame in which the body of the actor was in an approximated horizontal position, and (3) t3 = occlusion began after the video frame before the feet pass the height level of the vaulting box. This cutting procedure led to a total of 54 video sequences of handspring performances that were integrated into a computer-based perception test.

Computer-based perception test. The aforementioned 54 video sequences were integrated into a computer-based perception test. A trained research assistant introduced the computer-based perception test to each individually tested participant. In the first step, the participant was shown six handsprings on vault, differing in movement quality and movement duration. This was done for orientation and calibration purposes. In a second step, the participant was asked to predict the landing position of each individual performance of the 54 handsprings. Therefore, each of the video sequences of the handsprings was presented in real-time on a computer monitor. After the handspring on vault was shown, the participant predicted the landing position of the toes on the landing mat of the handspring just presented by moving the mouse pointer to the landing mat and confirming this choice by pressing the space key on the computer keyboard. A white cross represented the mouse pointer, and the absolute pixel position of the mouse pointer (mid position of white cross) was recorded for each prediction (Figure 1-c). The test order of the trials was randomized for each participant within each test and between the pretest and the posttest, in order to control for sequence effects. The computer-based perception test took approximately 15 minutes to complete.

The experiment was conducted in three phases. The first phase comprised the first gymnastics lesson of the semester. The students arrived at the gymnasium, completed the informed consent form and the computer-based perception test (pretest).

The second phase was the learning period. It consisted of four training sessions of 80 to 90 minutes per session, carried out over a 4-week period. Each individual session began with a 15- to 20-minute warm-up phase, including physical preparation exercises and lead-up activities. Then, a learning phase of 45 to 60 minutes was conducted, in which the students went through the methodical progression. Each training session ended with a 10- to 15-minute cool-down period. During each session, the students were allowed 20 to 30 practice trials. Different key instructions were systematically integrated in the methodical progression. Verbal feedback was provided as summary feedback on the movement quality of three to five observed attempts. Manual assistance was systematically integrated into the methodical progression, and provided when necessary. In the third phase of the experiment, the participants of the experimental group and the participants of the control group were asked to complete the computer-based perception test for a second time (posttest). The students were debriefed after completing the computer-based perception test.

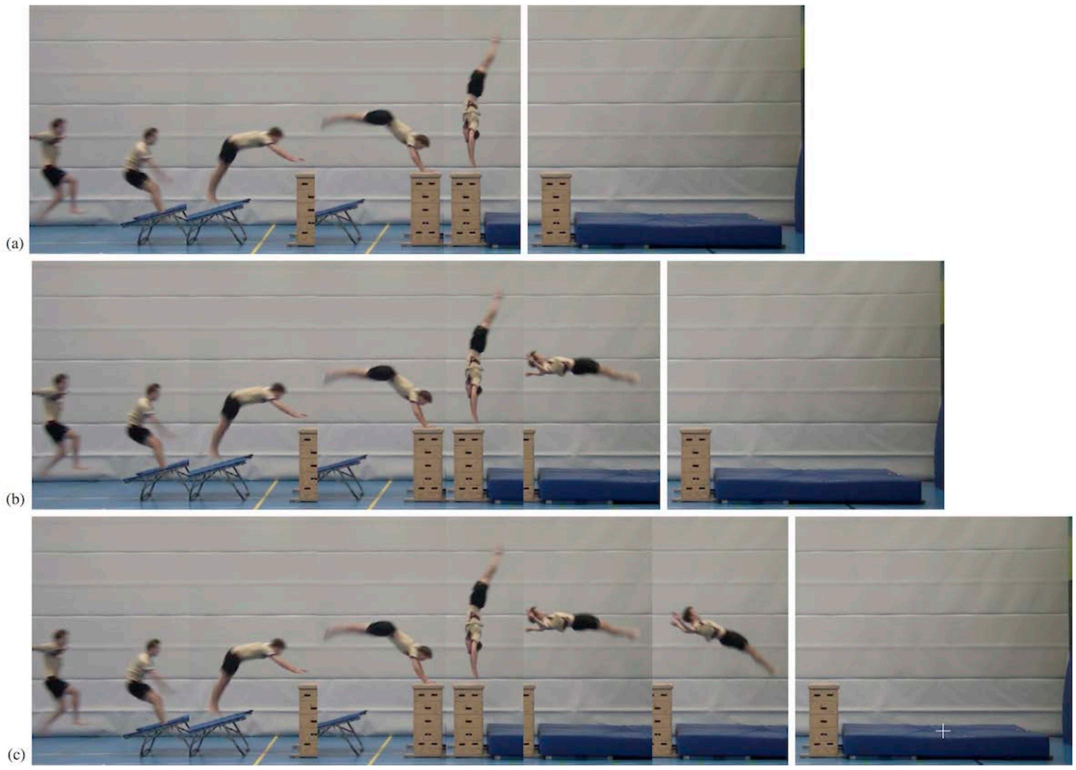

Figure 1. *Picture sequences illustrating the cut handspring video sequences in the three experimental conditions prior to the occlusion: (a) take-off from the vaulting box, (b) actors' body in approximated horizontal position during second flight phase, (c) actors' feet at vaulting box' height level. The white cross on the right side of the Figure characterizes the mouse pointer during the computer-based perception test. During the Occlusion Window, the gymnasts' body was completely occluded in the video sequences while only the vaulting box and the landing mat were visible.*

A significance criterion of α = 5% was used for all results reported. In a first step, the differences between the values for absolute pixel positions of all landing position estimations and the actual landing positions were calculated for each dataset (Magill, 2011). In a second step, the differences were averaged for each participant to give a single final value for the precision of the landing position estimations. In a third step, these final values for the precision of the landing position estimations were transformed into real world units (meters). Finally, and in order to assess differences in the estimations of the landing positions between groups, tests, and video durations, a 2 (*Group*: Experimental Group vs. Control Group) × 2 (*Test*: Pretest vs. Posttest) × 3 (*Occlusion Window*: t1 vs. t2 vs. t3) univariate analysis of variance was calculated, taking the precision of landing position predictions as dependent variable. Cohen's *f* was calculated as effect size for all significant *F*-values (Cohen, 1988). In order to explore how overall effects were driven by differences between Test and Occlusion Window for each of the two groups, post hoc analyses were carried out using the Tukeys' HSD post-hoc test (Knudson, 2009).

RESULTS

The first hypothesis was that participants who successfully acquired the handspring should outperform participants of a control group who was not asked to learn the handspring in the visual perception task. The second hypothesis was that participants who learned the handspring should also exhibit better test performance under earlier occlusion windows as compared to participants of a control group. The mean values for landing position predictions are presented in Figure 2.

The ANOVA revealed an interaction effect of Test × Group for the precision of landing position predictions, $F(1, 34) = 4.21$, $p = .048$, Cohen's $f = 0.35$, achieved power > .95. Post hoc analyses revealed that the participants of the Experimental Group exhibited better landing position predictions in the posttest as compared to the pretest for all three Occlusion Windows. Additionally, participants of the Experimental Group exhibited better landing position predictions in the posttest in Occlusion Windows t2 and t3, compared to the participants of the Control Group. The ANOVA revealed an additional significant main effect of Occlusion Window for the precision of the landing position predictions, $F(2, 68) = 14.02$, $p < .05$, Cohen's $f = 0.64$, achieved power > .95. Post-hoc analyses revealed that participants estimated the landing position most precisely in the earliest occlusion window as compared to the remaining occlusion windows.

DISCUSSION

The aim of this study was to address the question if participants who learned a novel motor skill exhibit predictable changes in visual perceptual processes when observing the acquired motor skill? The first hypothesis was that participants who successfully acquired the handspring over a vaulting box should outperform participants of a control group who were not asked to learn the handspring in a visual perception task. The second hypothesis was that participants who learned the handspring should also exhibit better test performance under earlier occlusion windows as compared to participants of a control group. Students were asked to learn the handspring performed over a vaulting box. Participants' predictions of landing positions of the handsprings were evaluated in a visual perception test. The results revealed that the participants of the Experimental Group exhibited more precise landing position predictions in the posttest as compared to the pretest for all three Occlusion Windows. Participants of the Experimental Group also outperformed participants of the Control Group under Occlusion Windows t2 and t3 in the posttest. Furthermore and most surprising, participants estimated the landing positions most precisely when the end of video sequences was one video frame after take-off from the vaulting box (Occlusion Window t1) as compared to the remaining two occlusion windows.

Participants seem to improve their ability to visually perceive a gymnastic skill by acquiring the skill by themselves, thus arguing in favor of a selective influence of motor skill acquisition on visual perception of the acquired motor skill (Casile & Giese, 2006). This result is in line with the assumption that observers' own action system contributes to the visual perception of motor skills (Blake & Shiffrar, 2007). Skilled observers are able to better estimate the landing position of a handspring, even when the handspring is depicted from an external perspective, as compared to unskilled observers, which is similar to empirical evidence provided by Loula et al. (2005). Further research emphasizes, that this result may not be explained by visual experience alone but is rather a result of both, motor and visual experience (Loula et al., 2005).

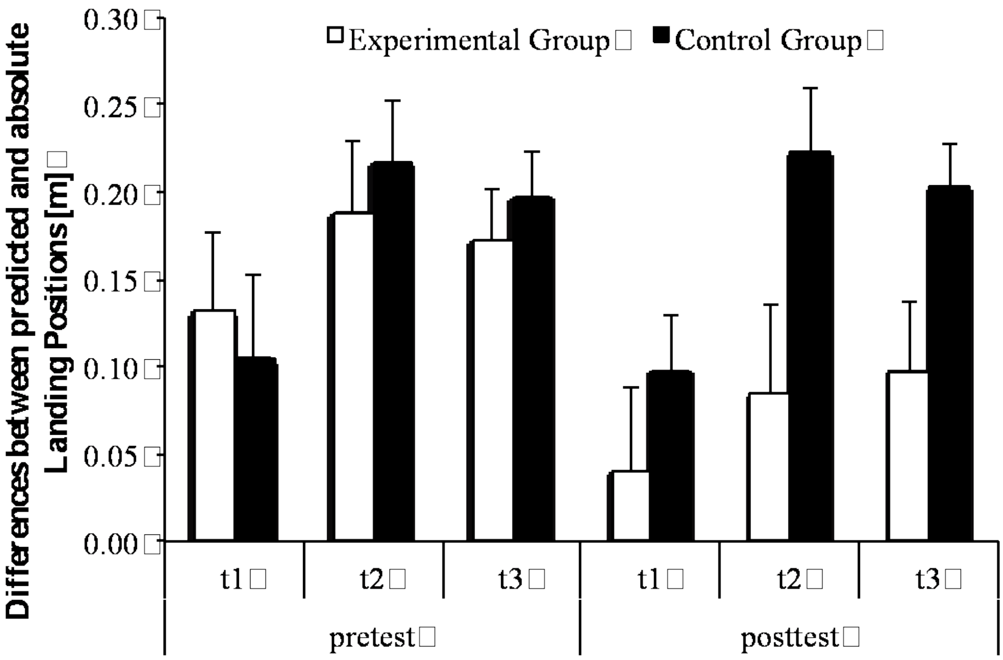

*Figure 2. Differences between predicted and absolute landing positions in meters. Zero values denote exact prediction of absolute landing position. The larger the values, the less precise the landing position predictions were. t1 to t3 denote the different occlusion windows: t1 = occlusion began at first video frame after take-off from the vaulting box, t2 = occlusion began after the video frame in which the body of the actor was in an approximated horizontal position, and t3 = occlusion began after the video frame before the feet pass the height level of the vaulting box' (see Figure 1). Note: * denotes significant difference according to post-hoc test (p < .05).*

Experts are thought to be better at picking up advance information in visual perception tasks (Blake & Shiffrar, 2007; Raab et al., 2009; Savelsbergh et al., 2002; Williams et al., 1999). However, and most surprising, the participants of the experimental group and the control group exhibited the best estimations of landing position under the earliest occlusion window. Comparing the handspring over a vaulting box with skills that were used in previous experiments, such as tennis services or penalty kicks in soccer (Mann et al., 2010; Savelsbergh et al., 2002), the handspring may contain a different information structure for observers, which may at least in part be grounded in the biomechanics of the skill.

From a biomechanics point of view, the landing position is determined by the bodies' take-off velocity at the end of the repulsion phase, the bodies' angular momentum during the flight phase, and the control of the bodies' moment of inertia, leading to a particular posture prior to touch-down (Prassas, Kwon & Sands, 2006). The bodies' angular momentum is constant during the flight phase and the bodies' moment of inertia is usually only subjected to small changes until touch-down (Heinen, Jeraj, Thoeren & Vinken, 2011). Therefore, one may speculate that information is already optimal for an observer at the end of the repulsion phase to estimate landing position in handspring, with a higher information density (e.g., 'seeing' more of the flight phase before predicting the landing position) leading to a reduced performance in predicting landing position (Ma, 2012; Luis & Tremblay, 2008). However, if information from the second flight phase is missing to the observer, he/she may not be able to estimate the quality of the second flight phase, which could also be an important aspect for coaches, judges and spectators.

There are some critical issues within the design of this study that need to be taken into account in further experiments and three specific aspects will be highlighted. First, handspring performances of gymnasts not belonging to the study sample were used to prepare the video sequences in the visual perception test. However, assuming, that an actor is most sensitive to his or her own actions (Blake & Shiffrar, 2007), a subsequent study should incorporate this distinction on a methodological level by evaluating the landing position predictions in video sequences where the participants observes his-/herself as compared to video sequences in which the participant observes other gymnasts (Knoblich & Flach, 2001). Second, neither participants' gaze behavior when watching the video sequences was measured, nor spatial occlusion techniques were utilized in the visual perception test. Measuring gaze behavior and/or using spatial occlusion techniques in a subsequent study could answer the question on which informational sources the participants based their landing position predictions (Mann et al., 2010). It could furthermore be of interest to systematically manipulate the duration of the occlusion windows in order to explore the relationship between the occlusion window duration and the likelihood of significant differences in estimating landing positions between participants and groups. Third, one may argue, that the students in this experiment also acquired visual experience just by taking part in the lectures and thereby observing other students performing the handsprings. However, during practice, the amount of visual experience in observing handspring landings was rather minimal due to the fact, that the students always started from the running track, far behind the vaulting box, and were therefore not able to observe the exact landing position of other students. Nevertheless, it is argued, that the distinction between visual and motor experience is an important one, and should be addressed in further studies.

There are some practical consequences of this study so far. First, it is argued that the results of this study reveal implications for motor skill acquisition in general. Participants were able to better predict specific aspects of a complex gymnastic skill, an aspect that is especially of high relevance in school and training settings, when teacher or coaches have to promote motor learning of others (e.g., students/pupils). It is therefore argued, that teachers and/or coaches are potentially better in teaching and/or coaching skills which belong to their own motor repertoire, thus resulting in better instructions and more precise feedback. Second the results underline the importance of motor expertise when estimating specific parameters in the motor behavior of others. In technical sports such as gymnastics, one could at least speculate about the potential positive effects of implementing motor skill learning in the education and training of judges and referees. Taken the results of our study together, it is stated, that as a learner acquires a motor skill in gymnastics, this changes the way the learner perceives that skill.

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