JUDGING PERFORMANCE IN GYMNASTICS:

A MATTER OF MOTOR OR VISUAL EXPERIENCE?

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Abstract

We addressed the question if laypeople with motor experience in gymnastics evaluate gymnastic performance similar to judges with only visual experience in the same domain. In addition we sought to explore the (biomechanical) sources of information that may account for the evaluation of gymnastics skills. We predict that laypeople rate handsprings on vault similar as expert judges and that gymnastics judges' scores are related to time-discrete kinematic characteristics whereas laypeople's scores are related to the form-aspect of the skill. 23 gymnastics judges and 23 laypeople rated handsprings on vault. Laypeoples' scores were in average lower than gymnastics judges' scores when judging handsprings. Laypeoples' scores were predicted well by time-continuous kinematic parameters whereas judges' scores were predicted well by time-discrete characteristics of the handsprings. We conclude, that judging in gymnastics can be facilitated by either own motor experience or specific visual experience.

Keywords: handspring, kinematic analysis, judges, laypeople.

INTRODUCTION

Perceiving the actions of other people is one important skill for judges, coaches and athletes in the sports domain and especially in gymnastics. Gymnastic judges have to correctly estimate the movement quality with regard to official international or national guidelines (Dallas & Kirialanis, 2010). Research has shown that both, visual and motor experience, may account for correctly estimating the movement quality of other people (Loula, Prasad, Harber & Shiffrar, 2005; Blake & Shiffrar, 2007). However, two questions remain open: The first one is, on which informational source(s) this estimation is predominantly based on. The second one deals with changes in informational source(s) as a function of the amount of visual or motor experience the observer exhibits. In the present study we therefore addressed the question if laypeople with motor experience in gymnastics evaluate gymnastic performance similar to judges, which have only visual experience in the same domain. In addition we sought to explore the (biomechanical) sources of information that may account for the evaluation of gymnastics skills.

Empirical evidence suggests that judges outperform laypeople in judgment tasks, mainly because they differ in the organization and activation of their

knowledge representations for the judged skills (Ste-Marie, 2003). Judges are better at anticipating upcoming gymnastic elements from previous information (Ste-Marie, 1999) and they know which information is relevant when judging a specific movement in their domain (Bard, Fleury, Carrière, & Hallé, 1980). Following this, expert judges are better in detecting movement errors or determining deviations from movement templates than laypeople (Plessner & Schallies, 2005; Ste-Marie & Lee, 1991) and they exhibit significantly greater depth and breadth in their declarative knowledge base (Ste-Marie, 2000). This is mainly because they have accumulated a large amount of visual experience over time. However, when we observe someone performing a motor skill, corresponding representations in our action system are automatically activated, depending not only on the amount of experience we have accumulated over time in imagining and observing, but also in planning and executing an action, suggesting that both, motor and visual experience, define visual sensitivity to human action (Blake & Shiffrar, 2007; Loula et al., 2005).

Loula et al. (2005) investigated how well observers are able to recognize themselves, friends or strangers from point-light displays of various actions (Experiment 1 & 2 of Loula et al, 2005). In order to generate point-light display, the authors attached reflective white markers to participants' major joints and head. The participants were also dressed in black clothes. When being filmed, only the reflective markers remained visible (cf., Johansson, 1973). If motor and visual experience determines visual sensitivity to human movement, then observers should be most sensitive to their own actions and more sensitive to actions of their friends than to actions of strangers. Participants viewed displays of point-light sequences of actions of themselves, their friends and strangers performing various actions. In actor identification and discrimination tasks, sensitivity to one's own actions was highest. Visual sensitivity to friends' was higher

than to stranger's actions. The authors concluded that both, motor and visual experience define visual sensitivity to human action.

Knoblich and Flach (2001) had participants predicting the landing position of dart throws at a target board after watching video clips of displaying either themselves or somebody else throwing the dart. They found out that the predictions were more accurate when participants watched themselves acting. The results confirmed the assumption that observers are more sensitive to actions most familiar to them and less sensitive to actions unfamiliar to them. This effect also occurs when people learn new movements. Casile and Giese (2006) could show that motor learning influences later perceptual performance. The authors had blindfolded participants learn novel arm synchronization patterns. Relative to a pre-testing session all participants showed improved post-learning visual recognition. It was concluded that motor learning had a direct influence on action recognition that is not mediated by visual learning.

From this point of view, not only visual but also motor experience defines people's sensitivity to human action recognition. However, the observation of the same action may rely on different (biomechanical) informational sources, depending on the amount of visual or motor experience the observer has accumulated over time (Blake & Shiffrar, 2007). As a consequence, two questions arise: The first one is: On which informational source is this estimation is predominantly based on? The second one is: Does the estimation and/or the informational source change as a function of the amount of visual or motor experience the observer exhibits?

Given that for instance expert judges' scores should by definition reflect the quality of the performed skill, one could assume relationships between judges' scores and kinematic parameters (e.g. Atiković & Smajlović, 2011; Takei, 1998, 2007; Takei, Blucker, Nohara, & Yamashita, 2000). In several studies, kinematic variables of

several skills performed on the gymnastic's vault were analyzed and related to the judge's scores by correlation- and regression-techniques. A common finding is that about 50 to 60% of the variation of the judges' scores can in general be explained by the variation of a few kinematic parameters. One major shortcoming of the mentioned studies is that the form-aspect of the movements to be judged is neglected, because only time-discrete parameter values were analyzed, without paying attention to their time-course. However, there is compelling empirical evidence, that time-discrete kinematic parameters do only in part capture the form-aspect of movements (Jaitner, Mendoza, & Schöllhorn, 2001), and a more holistic impression of a movement could be of high relevance when judging a skill in gymnastics (Arkaev & Suchilin, 2004).

In the current study, we compared gymnastics judges to laypeople. Gymnastic judges exhibited specific visual experience due to their education, but no motor experience. Laypeople were able to execute the skill they should judge in our experiment but had neither gymnastics judging experience nor specific knowledge of the judging guidelines of the International Gymnastics Federation (FIG, 2009), and thus they had no specific visual experience of the skill.

We evaluated the judgments of handsprings on vault in gymnastics. Our first assumption was that gymnastics judges with specific visual experience do not differ from laypeople with specific motor experience when judging handsprings on vault, because both, motor and visual experience may account for a precise judgment. Our second assumption was that judge's scores are related to time-discrete characteristics of the handspring vaults because expert judges know better which information is relevant when they are to judge a specific movement in their domain, whereas laypeople's scores are related to the form-aspect of the movement pattern, mainly because they might rely their estimations more on a holistic impression of

a skill, rather than on specific parameters (Jaitner et al., 2001; Takei, 1998).

METHODS

$N = 23$ gymnastics judges (experts; age: median = 35 years , range = 34, quartile range = 20) and $N = 23$ students of Sport Sciences (laypeople; age: median = 27 years, range = 25, quartile range) were recruited to participate in this experiment. We derived the number of participants from a power analysis when expecting a medium effect (Cohen's $f > 0.25$) with type I error probability of 5%, and type II error probability of 20%. All laypeople had specific motor experience in gymnastics due to their successful participation in gymnastics courses at the German Sport University Cologne. More specifically all laypeople were able to perform the handspring on vault by themselves without any guidance technique. They had neither gymnastics judging experience nor specific knowledge of the judging guidelines of the International Gymnastics Federation (FIG, 2009). All expert judges had an average experience of judging gymnastics skills of 8 ± 1 years and a valid judging license of the German Gymnastics Federation. All judges had some basic motor experience in gymnastics, which is typical for gymnastics judges, but none of them reported to ever be able to perform the handspring on the vault. All participants were asked to participate in an experiment on perceptual processes in the evaluation of gymnastic performances. They were informed about the procedure of the study and gave their written consent prior to the experiment, which was carried out according to the ethical guidelines and with the approval of the University's Ethical Committee. After the experiment they were debriefed and received a chocolate bar as a reward for their participation.

Preparation of video sequences. Video sequences of $N = 30$ female gymnasts (age: 18 ± 5 years) performing handsprings on vault were used in the experiment. All female gymnasts had at least seven years of experience with a minimum of six hours

training per week. The video sequences were recorded during training sessions. All 30 gymnasts were asked to perform the handspring three times and were advised to perform the formal process like they would do in competition, hence, announcing to the judge prior to the performance and give notice of completion after landing. Their performance was videotaped with two digital video cameras (50 Hz) which were placed at a distance of 15 m from the vaulting table. One camera recorded the gymnasts with a pan shot, simulating the judge's perspective. We wanted to simulate the natural perspective of the judges to control for possible influences of the observation angle on their judgments (Plessner & Schallies, 2005). The second camera was stationary and videotaped the performance orthogonal to the movement direction which was used for two dimensional movement analyses.

We used two validation steps in the preparation of the video sequences. First, two gymnastics coaches with national experience were independently asked to serialize the three performances of each gymnast in terms of their movement quality. They could use a laptop computer to play back the video sequences in slow motion whenever needed. There were no differences in their choice for the best handspring performance of each gymnast so that in each case the handspring with the highest quality could be picked out for further preparation of the experiment.

In the second step of the validation procedure, three judges with an international license and a judging experience of at least ten years who were not part of the study sample, rated the $N = 30$ video sequences in a random manner to ensure that they represent a typical sample one encounters in a regional gymnastics competition. The videos were shown in a randomized order on a laptop computer. The judges were independently asked to rate the performances on a 7-point scale ranging from 1 = *not representative* to 7 = *representative* for a regional competition in gymnastics. This procedure ensured that all

gymnasts had a comparable performance level. Inter-observer reliability was calculated at $r = .82$ ($p < .05$) using the coefficient of intra-class correlation over all rated performances. From the judges' ratings, $n = 10$ video sequences had to be removed from the experiment, because they were rated less representative for a typical sample one encounters in a regional gymnastics competition.

Kinematic Analysis. The video sequences from the second camera that videotaped the performance orthogonal to the movement direction were used for kinematic analysis. The horizontal and vertical coordinates of eight points (body landmarks) defining a 7-segment model (Figure 1) of the human body were recorded for each frame using the movement analysis software *WinAnalyze 3D* (Mikromak, 2008).
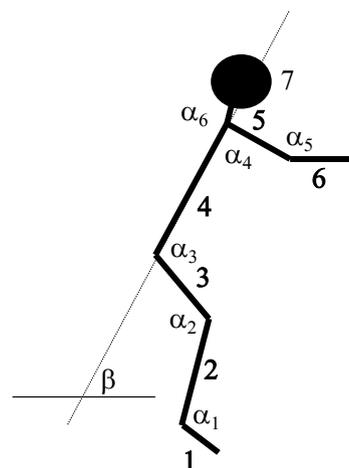

Figure 1. *Free body diagram of the 7-segment model used to calculate kinematic parameters of the handsprings. The numbers from 1 to 7 correspond to the body-segments. α_1 to α_6 describe the analyzed joint-angles and β symbolizes the orientation angle of the trunk.*

We have chosen the model outline similar to previous research (King & Yeadon, 2004). Because a single handspring on vault contains only regulatory movements of low frequency, a frame rate of 50 Hz was seen as sufficient for kinematic analysis of the handspring performances by an independent biomechanist. We applied a digital filter

(cut off frequency = 6 Hz) for data smoothing and calculated a mean temporal error of ± .02 s and a mean spatial error of ± .006 m from our data. Body-segment parameters were calculated on the basis of the individual anthropometric properties of each gymnast (Zatsiorsky, Seluyanov & Chugunova, 1990).

The kinematic analysis was performed in two steps. In a first step, we calculated time-discrete kinematic parameters for the handspring. With the help of a biomechanist who developed a deterministic model of the handspring and a top-level gymnastics coach, we chose nine kinematic parameters from our movement analysis data, that represent the most relevant judgment criteria from a biomechanical point of view in the three phases of the handsprings on vault, namely the first flight phase, repulsion phase and second flight phase (DTB, 2001). The distinct phases, the kinematic parameters as well as the corresponding criteria of the judging guidelines are presented in Table 1.

Table 1. *Distinct phases of the handsprings on vault and time-discrete kinematic parameters that were deviated from the judging guidelines of the German Gymnastics Federation (DTB, 2001; CM = centre of mass).*

Phase	Parameter	Judging criteria
First Flight Phase	Horizontal take-off velocity (CM)	Insufficient flight due to the technique of the handspring (too high or too low)
	Vertical take-off velocity (CM)	
	Moment of inertia at take-off	Insufficient body posture at take-off
Repulsion Phase	Moment of inertia at initial support	Insufficient body posture at initial support
	Contact angle of body and support surface	Insufficient contact angle
	Duration of repulsion phase	Effusive duration of repulsion phase
Second Flight Phase	Horizontal take-off velocity (CM)	Insufficient height and width of after-flight
	Vertical take-off velocity (CM)	
	Moment of inertia a touch-down	Insufficient body posture

In a subsequent step, time courses of angles and angular velocities of six joints (α_1 to α_6) of our 7-segment model as well as the orientation angle of the trunk (β) and its corresponding velocity were calculated for further process oriented data analysis (Jaitner et al., 2001). The use of the joint angles and angular velocities together with the orientation and its time dependent change of the trunk angle assured that the movements' description was physically complete. Each movement pattern of the $n = 20$ handsprings (including angles and angular velocities) consisted of 14 variables that were normalized by time and then compared to a reference handspring on vault. The data for the reference handspring performance was provided from an international licensed judge, used in judges' education programs in Germany.

A *similarity value* with arbitrary units was calculated by comparing each individual handspring pattern with the reference handspring (cp., Jaitner et al., 2001). While there were 14 variables per trial, a total of 280 comparisons were calculated. A similarity value of zero represented an identical movement pattern compared to the reference handspring. The

larger the value, the more dissimilar the two movement patterns were. With the calculation of the similarity values we could objectively quantify the form-aspect of the handsprings from a biomechanical point of view.

Performance rating. The judges scored the quality of each handspring on vault with regard to the judging guidelines of the German Gymnastics Federation (DTB, 2001) on a 9-point scale. A handspring could be scored with a maximum of eight points (perfect mastery of the handspring) and a minimum of zero points (major movement errors and/or aborting of performance). The laypeople also scored the quality of each handspring attempt on a 9-point scale comparable to the judges' scale, ranging from zero points for performing the movement with major movement errors or when aborting the performance and eight points for perfect mastery of the handspring.

A trained research assistant introduced the experimental task to each individually tested participant. The participant was shown $n = 3$ handsprings, differing in movement quality. This was done for orientation and calibration purposes. The research assistant provided the participant with the information that the first of the three handsprings is typically scored about four points, the second is scored about seven points, and the third is scored about one point in a regional competition. After the introduction, the participant was asked to rate each individual performance of the $n = 20$ handsprings. Therefore, each of the video sequences of the handsprings on vault was presented in real-time with a data projector on a silver screen with a diagonal of 2.50 meters. The participant was seated at a distance of 3.00 meters from the silver screen. After the handspring on vault was shown, the participant rated the performance of the gymnast just presented by typing the score into a laptop computer. The participant was given the chance to make notes after watching each handspring on vault, prior to giving a final score for each handspring performance. The test order of

the trials was randomized for the participants to control for sequence effects. The experimental task took approximately 25 minutes to complete. After the experiment, inter-observer reliability was calculated for both, the judge's and the laypeople's group at $r = .78$ and $r = .82$ ($p < .05$) respectively using the coefficient of intra-class correlation over all trials.

A significance criterion of $\alpha = 5\%$ was established for all results reported. In order to assess differences in the performance ratings between the both groups, a Mann-Whitney U-Test was calculated, including participants' performance rating scores of the handspring on vault as dependent variable. In addition, Spearmans' rho between the ranking lists of the laypeoples' and the gymnastic judges' scores was calculated as an criterion to which degree both groups judge the handspring in a similar fashion.

In order to assess relationships between movement kinematics and judge's and laypeople's scores, in a first step, we used multiple linear regression analysis to predict the laypeoples' and judges' scores for the handsprings on vault from the nine analyzed kinematic parameters. Therefore, the scores for each trial were averaged in the groups to give a final performance score. In the second step, we used correlation analysis to relate laypeople's and judges' scores to the *similarity values* of the handsprings on vault. A similarity value of zero represented an identical movement pattern compared to a reference handspring. The larger the value, the more dissimilar the two movement patterns were (see Kinematic Analysis section).

RESULTS

Performance Rating

Our first assumption was that gymnastics judges with specific visual experience do not differ from laypeople with specific motor experience when judging handsprings on vault. The Mann-Whitney U-Test revealed a significant difference between the two groups, $U = 59$,

$Z = -3.82$, $p < .01$. In average, laypeople tended to rate all performances about one point lower compared to the gymnastics judges (Figure 2). In addition it was found that the laypeople's ranking list for the video sequences was correlated at $r_S = .87$ ($p < .05$) with the judge's ranking list. The overall pattern of results provides an indication that the ratings of the laypeople were similar to the ratings of the judges.
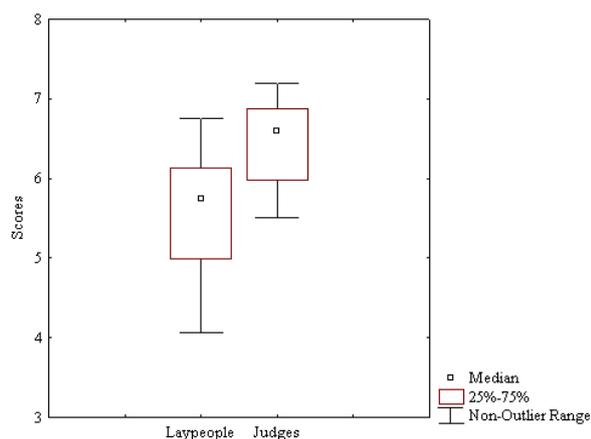

Figure 2. *Box plot of the judgments of the handspring vaults of the laypeople and the gymnastic judges.*

Kinematic Parameters and Participants' Scores

Our second assumption was that the judges' scores are related to the kinematic characteristics of the handspring vaults, whereas the laypeoples' scores are related to the form aspect of the movement pattern. We found that judges' scores could be predicted well by the time-discrete kinematic parameters whereas laypeople's scores could be predicted better by the similarity value of the process analysis (form-aspect of the handsprings on vault).

In detail, the variation of laypeoples' scores for the digital video sequences could be explained by an adjusted $R^2 = .41$. However, the overall F-test of the relationship between the laypeople's scores and the kinematic parameters was not significant, $F(9, 10) = 2.39$, $p = .09$, Cohen's $f = 0.69$. The adjusted coefficient of determination of the judges' scores for

the digital video sequences could be calculated at $R^2 = .68$ with the kinematic parameters as predictors. The F-test for the regression model was significant, $F(9, 10) = 5.49$, $p < .05$, Cohen's $f = 2.12$

The results of the correlation analysis showed negative significant product-moment correlation coefficients for the laypeople's scores of the video sequences and the similarity values of the kinematic analysis, $r = -.59$ ($p < .05$). A negative correlation coefficient indicates higher scores associated with smaller similarity values and vice versa. The product-moment correlation coefficients for the judges' scores of the digital video sequences and the similarity values were not significant, $r = -.37$ ($p = .10$).

DISCUSSION

The aim of this study was twofold: At first, we sought to evaluate the judgments of laypeople with motor experience, and of gymnastics judges with visual experience when observing handsprings on vault. In addition we sought to explore the (biomechanical) sources of information that may account for the evaluation of gymnastics skills. Our first assumption was that gymnastics judges with specific visual experience do not differ from laypeople with specific motor experience when judging handspring vaults. Our second assumption was that the judges' scores are related to the kinematic characteristics of the handspring vaults, whereas laypeople's scores are related to the form aspect of the movement pattern. Therefore, judges and laypeople were asked to judge gymnastics handspring vaults. Kinematic parameters were statistically related to the scores of both groups.

A surprising result was, that laypeople rated all performances significantly lower compared to the gymnastics judges, whereas, laypeople rated the handspring performances by ranking similar to the judges. When relating kinematic data and participants scores, judges' scores could be predicted well by time-discrete kinematic

parameters whereas the laypeoples' scores could be predicted better by the similarity value of the process analysis, capturing the form-aspect of the handsprings.

Differences or similarities in judging gymnastics skills can be explained by people's organization of memory representations (Bless, Fiedler & Strack, 2004) and their corresponding activation through perceptual stimuli (Wolfe, 1994). The categorization and encoding of a current stimulus relies on the structure and content of these representations. Judges have movement templates in their mind that cover "good", "bad", and "average" performances, so that they can in principle generate appropriate evaluations. Laypeople may not have specific movement templates, especially if they have no or only marginal visual experience with the skill to be judged.

Giving judgments in an experimental scenario, which was the case in our study, may also be influenced by particular calibration effects (e.g., Lackner & DiZio, 2000). One may speculate that either laypeople or judges systematically misjudged the movement quality. This could stem from the fact, that judges had specific movement templates in their mind which differed from the scores which the judges were normally used to judge for the three baseline-handsprings at the beginning of the experiment. Since laypeople were not familiar with the baseline-handsprings, they could potentially be more strongly influenced by the anchoring procedure of the baseline-handsprings.

A specific memory representation (i.e., movement template) could furthermore lead to the fact, that judges may allocate their attention to specific parts or phases of the handsprings, because these parts and phases are made explicit in the judging guidelines. For instance in vaulting, attention has to be allocated to the angle between the body and the support phase in the repulsion phase, because this is a criterion to be judged. Due to their intensive training, they already have acquired processing strategies together with substantial visual experience (Ste-Marie,

2003), so that they may extract the same specific information related to specific kinematic parameters.

Because judge's scores could be predicted well by time-discrete kinematic parameters, we claim, that specific visual experience is closely connected to the perception of time-discrete parameters, rather than to a more global impression of the handsprings. Focusing on time-discrete kinematic parameters of the handsprings could be in relation with the visual-pivot strategy, that some authors found in expert judges compared to novice judges (Bard et al., 1980). Fixating distinct areas for longer periods and using lesser saccades could help to focus visual attention on specific parts of the movement (e.g. pre-flight or repulsion), and therefore extracting time-discrete information. However, motor experience with the handspring on vault could also lead to a better perception of the handspring and motor experience seems to be stronger connected to the perception of the form-aspect of the movements to be judged. Already Kozlowski and Cutting (1978) pointed out, that judgments depend on some overall bodily features, and recently it could be shown, that different brain areas are activated due to the instruction given to the observers even if he or she looked at exactly the same stimulus material (Zentgraf et al., 2005).

We are aware of some critical issues within our design that need to be taken into account in further experiments and want to highlight three specific aspects. First, we contrasted judges with visual experience to laypeople with motor experience, but we did not integrate participants with neither visual nor motor experience in our design. Most of the existing studies show that experts in general outperform novices and laypeople in judging gymnastics skills (e.g., Ste-Marie, 1999). However, a replication of our study could integrate a third group consisting of judges with specific motor experience in gymnastics to extend our findings, especially with regard to the correlations between kinematic parameters and participants' judgments. Second, we did not

assess information rich areas for neither the laypeople nor the judges in terms of measuring participants' gaze behavior when watching the experimental stimuli. Therefore, we cannot be sure if judges' and laypeople's gaze behavior differs with regard to their spatial distribution or temporal dynamics. Measuring gaze behavior could be integrated in a replication of our study. Third, we used multiple linear regression analysis to predict laypeoples' and judges' scores for the handsprings on vault from the nine analyzed kinematic parameters. We acknowledge that different kinds of statistical analyses (e.g., neural network modelling, PCS-models) may potentially better predict judges' and laypeoples' scores from kinematic parameters. However, there may also be a trade-off between the degree of specificity and the amount of generalizability of such models (see for instance Glöckner, Heinen, Johnson & Raab, in press). As a consequence one of the next steps should be to analyze the *structure* of the relationships between kinematic variables and judges' or laypeoples' scores, assuming, that not all relationships maybe linear.

There are some practical consequences and implications of this study so far. First, we state, that own motor experience is as effective as visual experience when judging handspring vaults in gymnastics. Even laypeople with motor experience but no specific visual experience are able to give appropriate judgments of handsprings on vault in gymnastics. However, we furthermore conclude, that integrating specific tasks in judges' education courses, in which people gain experiences with simple mechanical relationships that govern complex gymnastics skills (like for instance the relationship between moment of inertia, angular momentum and angular velocity when performing somersaults) could potentially optimize the education process. In addition, it could be fruitful to analyze judges' visual and motor experience prior to competition in order to estimate the reliability of the final judgments.

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