MENTAL REPRESENTATIONS IN PHYSICAL EDUCATION STUDENTS' EVALUATION OF GYMNASTICS SKILLS

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Abstract

Research provides evidence that mental representations control human actions. It also shows a relation between mental representations and factors that might influence performance evaluation. The evaluation of motor skills figures prominently in physical education (PE) because it influences central tasks of teachers, like the provision of feedback and grading. Therefore, the purpose of this study was to examine the relation of PE students' mental representation structures and their evaluation of pupils' gymnastics skill performance. Mental representations and performance evaluations of the cartwheel and the roll forward were assessed in N = 30 PE students, by means of structural dimensional analysis - motoric and a video test. Participants' mental representations and performance evaluations were compared to an expert reference. Results revealed significant differences regarding the comparison of performance evaluations for a group of participants with more structured and a group with less structured mental representations, indicating that more structured mental representations are linked with a more precise performance evaluation. The study demonstrates that there is a relation between PE students' mental representation structure and their evaluation of gymnastics skills. Consequently, it is proposed to implement obligatory physical and mental training in the gymnastics training for future PE teachers, in order to develop expert-like mental representation structures and improve performance evaluation.

Keywords: *performance evaluation, SDA-M, roll forward, cartwheel.*

INTRODUCTION

The evaluation of motor performance is one of the central tasks of various actors in sports, such as coaches, referees, judges or teachers in physical education (PE). Observers' ability to evaluate performance influences the provision of feedback, affects the grading of pupils and can decide on victory and defeat in competitions (Nicaise, Cogérino, Bois, & Amorose, 2006; Plessner & Haar, 2006). Therefore, it is important to examine the processes that are taking place during performance evaluation more closely.

According to literature, the following four steps might characterize the evaluation of performance: 1) observation of the movement, 2) perception of the movement, 3) actual–target comparison, 4) detection of errors (Jeraj, Hennig, & Heinen, 2015). For a teacher in PE who has to evaluate the skill performance of a pupil, these steps could proceed as follows: In a first step, the teacher observes pupil’s skill performance and perceives a large amount of visual information. In a second step, this information has to be processed in the teacher's mind. The third step could be described as an actual-target-comparison, the comparison between real and expected performance of the learner, which leads to the fourth step, error detection. Strengths of the performance, as well as the weaknesses or errors, have to be established so that the teacher is able to judge learner’s skill performance (Cloes, Hilbert, & Piéron, 1995; Cloes, Premuzak, & Piéron, 1995; Knudson, 2013). It is suggested that during the third step of performance evaluation the visual perceptions of body positions are compared to mental representations of expected body positions throughout each phase of the movement (Hay & Reid, 1988). This focusing on the difference between the actual performance and a model of good form leads to error detection (Knudson, 2013). Thus, one important factor that influences performance evaluation might be observers’ mental representation structure of the skill to be evaluated, because mental representations in long-term memory act as a type of reference base for the planning and organization of behavior and are of utmost importance for the organization of motor actions (Bläsing, Tenenbaum, & Schack, 2009; Williams, Davids, & Williams, 1999). This is why the purpose of this study was to answer the question if performance evaluation is directly influenced by mental representations.

Theoretical approaches, such as the *theory of event coding* (Hommel, Müsseler, Aschersleben, & Prinz, 2001) and the *ideomotor approach* (Knuf, Aschersleben, & Prinz, 2001) emphasize the role of (mental) effect representations as the basis for intentional behavior (Hommel, 1996). These action-effect associations are excitable in both directions. It is, for instance, thought that the execution of a movement activates representations of a sensory effect and the excitation of an effect representation causes the execution of a movement (Kunde, 2006). Thus, the observation of learned movements leads to an activation of certain neural structures in comparison to unlearned movements (Cross, Hamilton, & Grafton, 2006). Further on, results showed an activation of similar neural structures during observation of movement patterns similar to the own field of expertise and a higher activation during observation of movement patterns identical to the own field of expertise (Calvo-Merino, Glaser, Grèzes, Passingham, & Haggard, 2005). Complex movements can thus be conceptualized as a cognitive network of sensorimotor information (Schack, 2004). The nodes within this network contain functional subunits (*Basic Action Concepts*; BACs) that are related to motor actions. Results from different lines of research addressing mental representation highlighted that the structure formation in long-term memory is built up on BACs. They are created through cognitive chunking of body postures and movement events concerning common functions in realizing action goals and include perceptual (visual, auditory, kinaesthetic) data and semantic content (Bläsing, 2010; Schack, 2010a). The better the order formation of these nodes, the easier information can be accessed and retrieved, leading to improved motor performance (Land, Volchenkov, Bläsing, & Schack, 2013). According to the *Cognitive Architecture Action-Approach* (Schack, 2004, 2010b) BACs are functional units for the control of actions at the level of mental representation. The level of mental representation is based on declarative as well as non-declarative knowledge in long-term memory (Bläsing, 2010).

To investigate the nature and role of long-term memory structures in complex motor performance, Schack and Mechsner (2006) examined the tennis serve. It was revealed that experts showed an organized hierarchical tree-like structure that was similar between individuals and was well matched with the functional and biomechanical demands of the task. Novices' mental representations were organized less hierarchically, more variable across individuals and less well matched with functional and biomechanical demands. Other studies replicated these results for example in the domains of dancing (Bläsing et al., 2009) and judo (Weigelt, Ahlmeyer, Lex, & Schack, 2011), supporting that mental representations differentiate between novices and experts and match to functional and biomechanical task demands. Supplementary, a study by Frank, Land, and Schack (2016) examined changes in the mental representation structure and outcome performance over the course of skill acquisition incorporating physical and mental practice. Their results show improvements in golf putting performance and a functional adaption of the mental representation structures across a physical practice group and a combined physical plus mental practice group.

If mental representations are the basis of action organization, they might be a basis of evaluation processes as well and thus might be a valuable indicator of expertise in performance evaluation. Advantages of experts in comparison to novices in skill execution may be traced back to more structured mental representations that facilitate movement execution, movement perception and anticipation of movement effects (Aglioti, Cesari, Romani, & Urgesi, 2008). Mann, Williams, Ward, & Janelle (2007) argue that experts have better domain-specific knowledge structures (i.e., mental representations) that optimize the picking up and processing of information (Gegenfurtner, Lehtinen, & Säljö, 2011).

Jeraj, Veit, Heinen, and Raab (2015) investigated factors that might be influencing the feedback process, which contains the above mentioned four steps of performance evaluation. For example, they list motor experience and biomechanical knowledge, factors that are related to mental representation structures. That is, athletes with higher motor experience and thus expertise show a better structured mental representation that matches with the biomechanical demands of the motor action (Schack & Mechsner, 2006).

In a study by Pizzera (2012), gymnastics judges were asked to rate gymnasts performing a balance beam skill regarding pre-determined criteria in a video test. The aim of the study was to investigate how gymnastics judges utilize their own experiences in the sport as sources of information. Decision quality between judges who could perform the skill on the balance beam themselves, thus have motor experience in this specific gymnastics skill, and those who could not was compared using a reference score. Results showed that judges with specific motor experience perform better than those without. In addition, Heinen, Vinken, and Velentzas (2012) concluded that judging in gymnastics could be facilitated by either own motor experience or specific visual experience. When judging handsprings, laypeoples' scores were in average lower than gymnastics judges' scores. Considering the results of Pizzera (2012) and Heinen et al. (2012) that motor experience leads to a more precise performance evaluation and the aforementioned relation of mental representations and motor experience, one could assume that a better structured mental representation might lead to a more precise performance evaluation as well.

Additionally, Hoffman and Sembiante (1975) asked baseball coaches, physical educators, and a control group to analyze the swing in baseball. The results showed a

74 % accuracy in diagnosing the swing for coaches, a 66 % accuracy for physical educators and a 44 % accuracy for the control group. No significant differences could be found between groups when analyzing a novel skill. These results suggest that performance evaluation is a function of skill familiarity, which in turn points to biomechanical knowledge. This strengthens the probable link between mental representations and performance evaluation since skill familiarity can be associated with a more structured mental representation of the skill (Land et al., 2013).

Another point of consideration for evaluation of performance is the task that has to be evaluated. Schack and Hackfort (2007) describe that every movement can be broken down into its structure and process, which implies the significance of the constituent parts of an action. Differences in structure and process of tasks may determine their difficulty. Studies could show a relation between task difficulty and strategies used by participant to solve tasks (e.g., Wulf, Töllner, & Shea, 2007). Hennig, Velentzas and Jeraj (2016) presented a study that determined possible differences between display formats of items used in *structural dimensional analysis - motoric* (SDA-M) in gymnastics. In this context they could show a task-related difference in difficulty, because solutions for the roll forward (a simpler task) were more similar to an expert structure than solutions for the cartwheel (a more complex task).

As the literature review indicates, mental representations control motor actions. Because perceiving and acting rely on the same representations, it is presumable that the evaluation of motor actions, or more specifically the actual-target-comparison, relies on these representations as well (Hommel, 1996). Thus, it would be important to know if observers' mental representations of a motor skill influence their performance evaluation. Furthermore, mental representations compose the knowledge base for human actions and are related to factors that might influence the evaluation process, such as motor experience (Schack & Mechsner, 2006). This is why it was assumed in this study that observers with better structured mental representations show a more precise performance evaluation as well. The aim of this study was to analyze the relation between PE students' mental representation structure and their evaluation of pupils' skill performance, addressing the question, if it is possible to show a direct link between mental representation structure and performance evaluation by means of the SDA-M.

Therefore, PE students were asked (1) to fill in two SDA-M questionnaires to assess their mental representation structure of the cartwheel and the roll forward, and (2) to rate videos of pupils performing a cartwheel and a roll forward. Two groups of participants were determined based on SDA-M results. Distinguishing criterion for the division of groups was the similarity of participants' mental representation structure to an expert reference structure. Thus, one *similar* (to mental representation structure of experts) group and one *dissimilar* (to mental representation structure of experts) group of participants were distinguished. Following the aforementioned argumentation, it was hypothesized that an expert-like mental representation structure has a positive influence on the performance evaluation. The more similar the PE students' representation structure to an expert reference structure, the more similar the performance evaluation of the motor skills to an expert rating. Or in other words, the better the mental representation structure, the better should be the performance evaluation. However, regarding the two skills cartwheel and roll forward, it was hypothesized that there is a task-specific difference in difficulty (Gerling, 2011; Hennig et al., 2016).

METHODS

In total, *N* = 30 PE students (pre-service PE teachers) (age: *M* = 22.80 years, *SD* = 2.40; gender: 18 male, 12 female) participated in this study. All participants were studying to receive their Master's degree to become teachers for PE. Representing a rather homogenous group of future teachers, participants were chosen, who were about to finish their studies and therefore on an approximately equal educational level. Prior to the beginning of the study, all participants were informed about the general procedure and gave their written consent. The study was carried out according to the ethical guidelines of the university's ethics committee.

Structural Dimensional Analysis - Motoric. To PE students' mental representations of the gymnastics skills cartwheel and roll forward, the *structural dimensional analysis - motoric* (SDA-M; Schack, 2012) was used. This experimental approach, permitting a psychometric analysis, proved itself as a reliable method to determine relations between functional sub-steps of a movement (*basic action concepts*; BACs) and the groupings of a given set of BACs (Velentzas, Heinen, Tenenbaum, & Schack, 2010). In a first step, a split procedure (see the following paragraph) on a set of BACs is performed, resulting in a distance scaling between the BACs. For the purpose of this study, a pre-determined set of eight BACs relating to the cartwheel and a set of seven BACs relating to the roll forward were used. Both sets of BACs were generated based on expert interviews and textbooks (see Hennig et al., 2016). In a paper-pencil questionnaire, pairs of two BACs are presented in randomized order, so that each of the BACs is being displayed together with another BAC (see Figure 1 as an example). Participants are asked to decide whether the two BACs presented together are related to each other during movement execution or not. To do so, participants chose either a negative or positive sign in the paper-pencil test. The splitting task is completed after each BAC has been compared to every other BAC of the set, so the questionnaires consisted of 21 item comparisons for the roll forward and in total 28 item comparisons for the cartwheel.

Video Rating for Performance Evaluation. To assess performance evaluation of the participants, a video test for each skill was conducted. Therefore, 19 seventh-graders were asked to perform both skills, the cartwheel and the roll forward, before and after a training phase. The video tests included a playlist of 38 video clips for the cartwheel and 38 video clips for the roll forward in randomized order. Each video clip was only shown once and participants were not able to pause or repeat the video clip to simulate real PE conditions. Participants scored the quality of each performance of cartwheel and roll forward with regard to a given set of criteria on a 10-point scale. Table 1 and Figure 2 illustrate the criteria for the evaluation of the two gymnastics skills. For each point of the mentioned criteria the pupil in the video fulfilled, participants noted one point on an evaluation sheet. Both skills could be scored with a maximum of ten points (pupil met the skill criteria in every point) and a minimum of zero points (pupil made major movement errors, not meeting skill criteria in any point).

Reference Structure and Gymnastics Skills. A group of four gymnastics experts was asked to participate in this study. Their mental representation structures, as well as their evaluation of pupils' performance of gymnastics skills, were determined as point of reference (see Data Analysis section). The experts reported *M* = 14.75 years of experience as gymnastics coaches. Experience and the ability to evaluate performance was the selection criterion for expertise in this study (Chi, 2006; Swann, Moran, & Piggott, 2014).

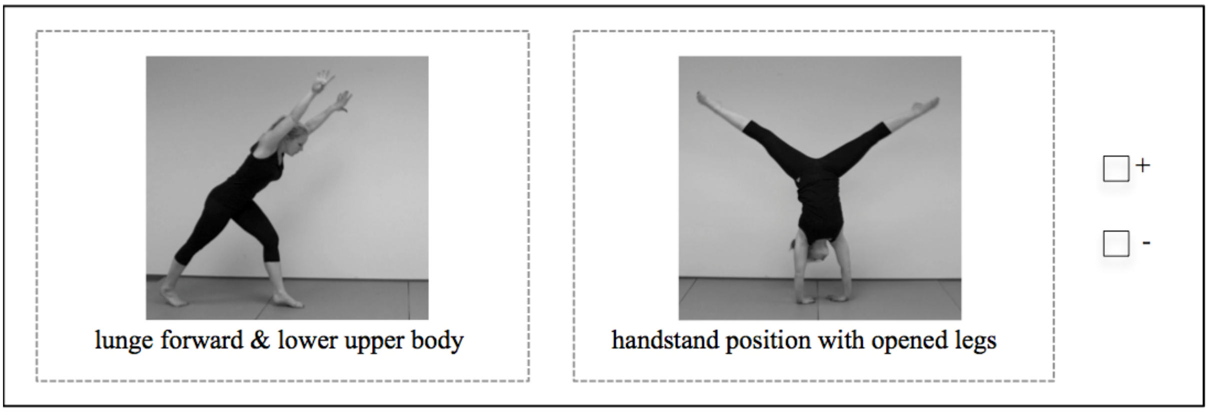

Figure 1. Example for one of the 28 item comparisons of the SDA-M questionnaire for the cartwheel. Participants had to choose either the negative or positive sign depending on whether the two BACs presented are related to each other during motor performance or not.

Table 1
Evaluation Criteria for the Judging of Pupils' Performance for the Gymnastics Skills Cartwheel and Roll Forward (see Figure 1).

No.	Cartwheel	Roll Forward
1	Standing straight & raising arms	Standing straight & raising arms
2	Twisting upper body	Squatting down
3	Positioning hands aligned on the floor one after the other	Putting arms forward shoulder width
4	Pulling up legs one after the other	Taking head to chest
5	Straightened legs and arms & body tension	Rolling in upper body
6	Handstand position with open legs	Placing back of the neck
7	Placing feet one after the other on the floor	Moving knees to chest
8	Setting body upright	Placing feet on the ground
9	Standing on both feet & balance	Standing up without using hands
10	Fluent movement sequences	Fluent movement sequences

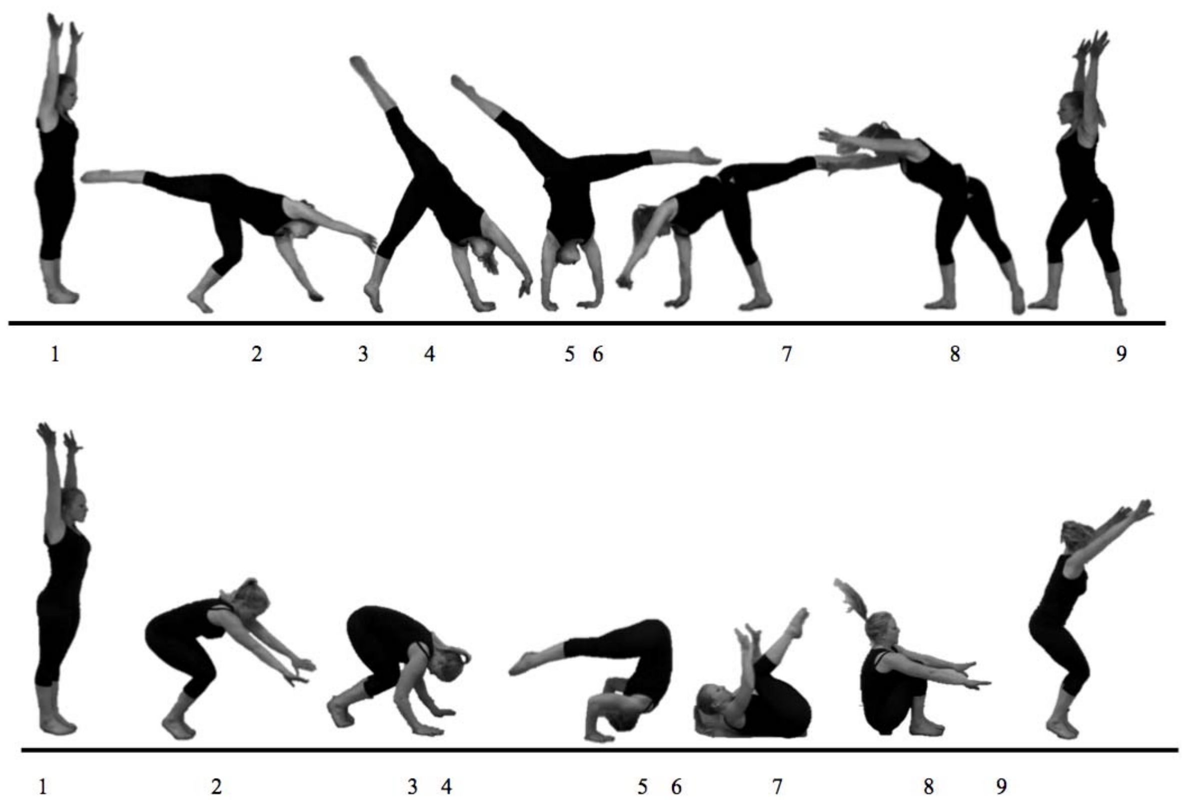

Figure 2. Sequences of pictures for the two gymnastics skills cartwheel (top) and roll forward (bottom), illustrating points one to nine of the evaluation criteria for the judging of pupils' performance (see Table 1). Point ten of the evaluation criteria refers to the whole movement and is not explicitly mentioned in this Figure.

The cartwheel and the roll forward were chosen to exemplify a more complex and a more basic floor exercise in gymnastics. While the roll forward is executed in the sagittal plane around a horizontal axis, the cartwheel includes rotations of the body around the longitudinal and the anteroposterior axis (Gerling, 2011; Figure 2). Both skills are part of the German curriculum of PE for Lower Saxony, in the experience and learning field of Gymnastics and Movement Arts that contains rolling, swinging, jumping and balancing (Ministry of Education and Cultural Affairs of Lower Saxony, 2007).

The study was conducted in the local university, where participants were asked to meet in a seminar room. Participants were informed about the general purpose and procedure of the study and completed the informed consent form as well as a questionnaire on their own experiences as former gymnasts. To ensure anonymous participation, an ID was used on the questionnaires. In order to avoid sequential effects, the procedure was realized in two phases with two sub-phases each, which are described in the following. The first group of participants (n_1 = 15) began with the cartwheel and proceeded with the roll forward, the second group of participants (n_2 = 15) began with the roll forward and proceeded with the cartwheel.

First, participants were instructed to fill in the SDA-M questionnaire for one of the skills (cartwheel or roll forward). In the SDA-M the subjects were asked to state for each of the BACs involved in performing the appropriate gymnastics skill whether it is functionally close to each of the other BACs or not. Participants chose either a negative sign (minus) or positive sign (plus) in the paper-pencil test depending on whether the element was judged as belonging to or not belonging to the reference (for further details see Schack & Mechsner, 2006).

In the second step, participants were instructed to read the given criteria according to which they would evaluate the skill. The playlist of videos was presented via laptop and data projector, presented on the wall in front of them. After the presentation of one reference video for the skill, participants had to rate 38 randomly presented video clips for the cartwheel and for the roll forward. They watched the video clip, which was shown only once in real time, and then noted their ratings in the appropriate columns on the evaluation sheet.

A significance criterion of $\alpha = 5$ % was defined a priori for all reported results. In order to test the main hypotheses, two separate *t*-tests for independent means were calculated. Cohen's *d* was calculated as an effect size for all reported *t*-values. Data were further analyzed in four steps:

First, for all SDA-M data collected, the splitting procedure (see Instruments) was applied. As a following step, a hierarchical cluster analysis was carried out to outline the structure of the given set of BACs (for details on SDA-M analysis, see Schack, 2012). In order to calculate the similarity/dissimilarity to the expert reference structure, the Euclidean distance for the comparison of each participant's *z*-matrix solution with the mean experts' *z*-matrix solution was calculated. To ensure comparability of the results for the different skills, the Euclidean distances of the comparisons were divided by the number of BACs (7 for the roll forward; 8 for the cartwheel).

Second, Euclidean distances were arranged according to size, so that two groups could be separated by median split: one *similar* (to mental representation structure of experts) group and one *dissimilar* (to mental representation structure of experts) group of participants. Thus, the *similar group* represents the group of participants with more structured mental representations and the dissimilar group represents participants with less structured mental representations.

Third, ratings in points for each video were arranged according to score, to compile a ranking with the best-rated video on first position and the video with the lowest rating on last position. In order to calculate the deviation to the reference performance evaluation, the mean of deviation from the reference ranking was calculated for each participant's ranking. Following, means and standard deviation of deviation of rankings for each group were calculated. A smaller deviation of rankings represents a more precise evaluation of the skills.

Fourth, in order to examine statistical differences between groups and tasks, *t*-tests for independent samples were conducted: An independent-samples *t*-test with *performance evaluation* as dependent variable and *mental representation structure* as independent variable (with the two groups: similar and dissimilar) for each task, the cartwheel and the roll forward. Furthermore, an independent-samples *t*-test with *performance evaluation* as dependent variable and *task* as independent variable (with the two groups: cartwheel and roll forward).

RESULTS

As a relation between mental representation and performance evaluation was assumed, both for the cartwheel and the roll forward, it was hypothesized that the more similar the PE students' representation structure to an expert structure, the more similar the performance evaluation should be to an expert rating. For the comparison of the results of a similar and a dissimilar group of PE students it was therefore hypothesized that there is a significant difference between groups. To verify this assumption, means and standard errors of deviation of rankings for a similar and a dissimilar group were calculated and in order to examine statistical differences between the two groups for the cartwheel and the roll forward, independent-samples *t*-tests were conducted.

Figure 3 displays that for the cartwheel as well as for the roll forward, the similar group shows closer values to the reference than the dissimilar group. Results of the *t*-tests revealed significant differences for the comparison of similar and dissimilar group for the cartwheel $t(28) = 1.729$, $p = .047$, Cohen's $d = 0.654$ and for the roll forward $t(28) = 2.234$, $p = .017$, Cohen's $d = 0.844$.

Regarding the comparison of the two skills cartwheel and roll forward, it was hypothesized that there is a task-specific difference. Means and standard deviation ($M \pm SD$) of the *performance evaluation* (deviation of the experts' ranking in points) for the two skills show that the deviation of the experts' ranking for the roll forward (1.315 ± 0.449) is smaller than for the cartwheel (1.603 ± 0.229). Results of the *t*-test showed a significant difference for the comparison of cartwheel and roll forward $t(28) = 3.154$, $p = .002$, Cohen's $d = 0.808$.

Overall, results displayed that the more similar the PE students' mental representation structure of the gymnastics skill compared to an experts' mental representation structure, the more similar the performance evaluation of this skill compared to an experts' performance evaluation. Regarding the tasks, results revealed that participants showed a significantly lower deviation from expert ranking for the roll forward in comparison to the cartwheel.

DISCUSSION

Research focusing on the storage of information in long-term memory provides evidence that mental representations control human actions (Hommel, 1996). Additionally, studies show a relation between mental representations and factors that might be influencing performance evaluation, such as visual and motor experience (Heinen et al. 2012; Schack & Mechsner, 2006). This is why the aim of this study was to analyze the relation between PE students' mental representation structure and their evaluation of pupils' skill performance, and thus, to answer the question, if the evaluation process is directly influenced by mental representations.

Results revealed that there is a relation between the mental representation structure and performance evaluation of PE students. In line with the hypothesis, the data indicate that the more similar the PE students' mental representation structure of the gymnastics skill compared to an experts' mental representation structure, the more similar the performance evaluation of this skill compared to an experts' performance evaluation. In other words, a better structured mental representation leads to a more precise performance evaluation.

First of all, these results indicate, that the structuring of mental representations is one important factor that influences the evaluation process of skill performance as it was assumed by the heuristic concept of Jeraj et al. (2015). Part of this process is the detection of errors, which is the result of an actual-target-comparison, the comparison between real and expected performances of the learner. The more structured the mental representation in long-term memory of the teacher, the better may be the actual-target-comparison, because the concept of how the expected performance of the learner should be like, may be clearer (Cloes, Hilert et al., 1995; Cloes, Premuzak et al., 1995; Jeraj, Hennig et al., 2015).

The results of this study complement findings of Pizerra (2012) and Heinen et al. (2012), since they report that motor and visual experience are influencing the judging process. Experts outperform novices in judging gymnastic skills – this can be traced back to their motor and visual experience but also (maybe on a superordinate level) to their mental representation structure of the motor skills. Furthermore, the result of Hoffman and Sembiante (1975), who suggested that teachers' performance evaluation is a function of skill familiarity, is supported by the results of the present study. A greater familiarity of an observer with a motor skill, the more structured the observer's mental representation structure of the skill and consequently, the observer's performance evaluation.

Focusing on the group of participants chosen in this study, it is important to consider that evaluation competency plays an essential role in PE. For example, central tasks of PE teachers are the provision of feedback, and the grading of pupils (Nicaise et al., 2006). In PE practice, it is essential to note that these tasks must be carried out in a short time frame. The results of this study indicate, that it might be possible to directly enhance teachers' performance evaluation by influencing and changing the mental representation structures in long-term memory of PE teachers. For example, through specific feedback or instructions developed based on the given structures or mental training programs combined with physical practice. Frank et al. (2016) showed improvements in motor performance and mental representation structures after mental and physical practice. Therefore, it should be considered to implement obligatory physical and mental training in the gymnastics training for future PE teachers.

Regarding the two skills cartwheel and roll forward, it was hypothesized that there is a task-specific difference. Following Hennig et al. (2016), the results suggest a specific role of the task to be assessed. Even though the number of criteria for the cartwheel and the roll forward were identical, it seems to be easier for the PE students to evaluate the roll forward. Different difficulty levels of motor skills might not only structure the mental representation but also affect observer's performance evaluation. The more structured the mental representation in long-term memory of the observer, the better may be the actual-target-comparison and this in turn might relate to task difficulty. The comparison between real and expected performances of the learner might be easier for an easy task.

There are limitations of this study and three specific aspects should be highlighted. First, it would be important not only to investigate mental representation structures of students but also of, for example, teachers with teaching experience of several years or even several decades. Groups of participants with different teaching experience could be compared, and the surveillance of the development of mental representations during a teachers' career could be interesting to focus on. By extending the selection criteria (e.g., concerning experience, age, area of work) for the group of participants, it may be possible to transfer the results to further groups, whose task is to evaluate motor performance, such as judges, coaches, commentators, and pupils. Referring to the first and second step of performance evaluation, observation and perception of the movement, not only different levels of experience should be taken into consideration but also factors that are hard to control like differences in perceptional or observational strategies. Second, two gymnastics skills were selected in this study to exemplify a more complex and a more basic floor exercise in gymnastics. For the purpose of this study the task selection was appropriate because of the defined evaluation criteria for gymnastic skills. But both skills can be categorized as closed skills. However, further research could focus on open skills with different demands, such as those skills that are performed in an unstable and dynamic environment (Gentile, 1972). Third, it could of course be possible to apply a more differentiated form of performance evaluation criteria, for example a grading of high, medium or low quality of the execution, as well as a different form of assessing mental representations (i.e., reaction times; Eysenck & Keane, 2000).

With regard to future research, it would be interesting to take a closer look at the relation between the mental representation structures of PE teachers and their pupils. An interesting question could be whether the development of learners' mental representations is influenced by their teacher's mental representation structure. This could help to provide insights into the communication between teachers and learners and possible ensuing difficulties.

CONCLUSION

It can be concluded that pre-service PE teachers use their mental representations of a motor skill, not only for their own motor performance but also as a basis for the evaluation of skill performance. Therefore, the acquisition of mental representation structures can be seen as important and useful for improving PE teacher training as well as training for professional observers in sports in general.

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REFERENCES

Aglioti, S. M., Cesari, P., Romani, M., & Urgesi, C. (2008). Action anticipation and motor resonance in elite basketball players. *Nature Neuroscience, 11*(9), 1109-1116.

Bläsing, B. (2010). The dancer's memory. Expertise and cognitive structures in dance. In B. Bläsing, M. Puttke, & T. Schack (Eds.), *The neurocognition of dance: Mind, movement and motor skills* (pp. 75-98). Hove: Psychology Press.

Bläsing, B., Tenenbaum, G., & Schack, T. (2009). The cognitive structure of movements in classical dance. *Psychology of Sport and Exercise, 10*(3), 350-360.

Calvo-Merino, B., Glaser, D. E., Grèzes, J., Passingham, R. E., & Haggard, P. (2005). Action observation and acquired motor skills: an FMRI study with expert dancers. *Cerebral Cortex, 15*(8), 1243-1249.

Chi, M. T. H. (2006). Two approaches to the study of experts' characteristics. In K.A. Ericsson, N. Charness, P. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge Handbook of Expertise and Expert Performance* (pp. 21-38). Cambridge, England: Cambridge University Press.

Cloes, M., Hilbert, J. M., & Piéron, M. (1995). Effects of an observation training program on feedback. Study of several cases. *Better teaching in physical education? Think about it!,* 249-266.

Cloes, M., & Premuzak, J., & Piéron, M. (1995). Effectiveness of a video training programme used to improve error identification and feedback processes by physical education student teachers. *International Journal of Physical Education, 32*(3), 4-10.

Cross, E. S., Hamilton, A. F. D. C., & Grafton, S. T. (2006). Building a motor simulation de novo: observation of dance by dancers. *Neuroimage, 31*(3), 1257-1267.

Eysenck, M. W., & Keane, M. T. (2000). Cognitive psychology: A student's handbook (4th ed.). Sussex: Psychology Press.

Frank, C., Land, W. M., & Schack, T. (2016). Perceptual-cognitive changes during motor learning: The influence of mental and physical practice on mental representation, gaze behavior, and performance of a complex action. *Frontiers in Psychology*, *6*(1981). doi: 10.3389/fpsyg.2015.01981.

Gegenfurtner, A., Lehtinen, E., & Säljö, R. (2011). Expertise differences in the comprehension of visualizations: A meta-analysis of eye-tracking research in professional domains. *Educational Psychology Review, 23*(4), 523-552.

Gentile, A. M. (1972). A working model of skill acquisition with application to teaching. *Quest, 17*, 3-23.

Gerling, I. E. (2011). *Basisbuch Gerätturnen* [basis handbook gymnastics] (7th ed.). Aachen: Meyer & Meyer Verlag.

Hay, J. G. & Reid, J. G. (1988). *Anatomy, mechanics, and human motion*. Englewood Cliffs, NJ: Prentice Hall.

Heinen, T., Vinken, P. M., & Velentzas, K. (2012). Judging performance in gymnastics: a matter of motor or visual experience. *Science of Gymnastics Journal, 4*(1), 63-72.

Hennig, L., Velentzas, K., & Jeraj, D. (2016). The measurement of mental representations within the context of motor actions, In: T. Heinen, I. Cuk, R. Goebel, & K. Velentzas (Eds.), *Gymnastics performance and motor learning: principles and applications* (pp. 89-117), New York: Nova Science Publishers.

Hoffman, S. J., & Sembiante, J. L. (1975). Experience and imagery in movement analysis. *British Proceedings of Sports Psychology*, 288-293.

Hommel, B. (1996). The cognitive representation of action: Automatic integration of perceived action effects. *Psychological Research, 59*(3), 176-186.

Hommel, B., Müsseler, J., Aschersleben, G. & Prinz, W. (2001). The theory of event coding (TEC): A framework for perception and action planning. *Behavioral and Brain Science, 24*, 849-878.

Jansen-Osmann, P. (2008). Die Bedeutung der Neurowissenschaft für die Sportwissenschaft. *Sportwissenschaft, 38*(1), 24-35.

Jeraj, D., Hennig, L., & Heinen, T. (2015). The error correction process – A heuristic concept. In T. Heinen (Ed.), *Advances in visual perception research* (pp. 193-202). New York: Nova Science Publishers.

Jeraj, D., Veit, J., Heinen, T., & Raab, M. (2015). How do gymnastics coaches provide movement feedback in training? *International Journal of Sports Science & Coaching, 10*(6), 1015-1024.

Knudson, D. V. (2013). *Qualitative diagnosis of human movement: improving performance in sport and exercise* (3rd ed.). Champaign: Human Kinetics.

Knuf, L., Aschersleben, G., & Prinz, W. (2001). An analysis of ideomotor action. *Journal of Experimental Psychology: General, 130*(4), 779-798.

Kunde, W. (2006). Antezedente Effektrepräsentationen in der Verhaltenssteuerung. *Psychologische Rundschau, 57*(1), 34-42.

Land, W. M., Volchenkov, D., Bläsing, B. E., & Schack, T. (2013). From action representation to action execution: exploring the links between cognitive and biomechanical levels of motor control. *Frontiers in Computational Neuroscience*, *7*, 1-14.

Mann, D. T., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology, 29*(4), 457-478.

Ministry of Education and Cultural Affairs of Lower Saxony. (2007). *Kerncurriculum für die Schulformen des Sekundarbereichs I*, *Schuljahrgänge 5-10*, *Sport [Core curriculum for the school types of secondary education*, *grades 5-10*, *sport]*. Hannover.

Nicaise, V., Cogérino, G., Bois, J., & Amorose, A. J. (2006). Students' perceptions of teacher feedback and physical competence in physical education classes: gender effects. *Journal of Teaching in Physical Education, 25*(1), 36-57.

Pizzera, A. (2012). Gymnastic judges benefit from their own motor experience as gymnasts. *Research Quarterly for Exercise and Sport, 83*(4), 603-607.

Plessner, H. & Haar, T. (2006). Sports performance judgments from a social cognitive perspective. *Psychology of Sport and Exercise, 7*(6), 555-575.

Schack, T. (2004). The cognitive architecture of complex movement. *International Journal of Sport and Exercise Psychology*, *2*(4), 403-438.

Schack, T. (2010a). Building blocks and architecture of dance. In B. Bläsing, M. Puttke, & T. Schack (Eds.), *The neurocognition of dance: Mind, movement and motor skills* (pp. 11-40). Hove: Psychology Press.

Schack, T. (2010b). *Die kognitive Architektur menschlicher Bewegungen: Innovative Zugänge für Psychologie, Sportwissenschaft und Robotik [The cognitive architechture of human motor actions: innovative approaches for psychology, sports science and robotics].* Meyer & Meyer Verlag.

Schack, T. (2012). Measuring mental representations. In G. Tenenbaum, R. Eklund, & A. Kamata (Eds.), *Measurement in Sport and Exercise Psychology*, (pp. 203-214). Champaign: Human Kinetics.

Schack, T., & Hackfort, D. (2007). An action theory approach to applied sport psychology. In: G., Tenenbaum, & R. C. Eklund (Eds.). Handbook of Sport Psychology (pp. 332-351). New York: Wiley.

Schack, T. & Mechsner, F. (2006). Representation of motor skills in human long-term memory. *Neuroscience Letters*, *391*(3), 77-81.

Steggemann, Y., Engbert, K., & Weigelt, M. (2011). Selective effects of motor expertise in mental body rotation tasks: Comparing object-based and perspective transformations. *Brain and Cognition, 76*(1), 97-105.

Swann, C., Moran, A., & Piggott, D. (2014) Defining elite athletes: Issues in the study of expert performance in sport psychology. *Psychology of Sport and Exercise, 16*, 3-14.

Velentzas, K., Heinen, T., Tenenbaum, G., & Schack, T. (2010). Functional mental representation of volleyball routines in German youth female national players. *Journal of Applied Sport Psychology, 22*(4), 474-485.

Weigelt, M., Ahlmeyer, T., Lex, H., & Schack, T. (2011). The cognitive representation of a throwing technique in judo experts–Technological ways for individual skill diagnostics in high-performance sports. *Psychology of Sport and Exercise, 12*(3), 231-235.

Williams, A. M., Davids, K., & Williams, J. G. P. (1999). *Visual perception and action in sport*. Eastbourne: Taylor & Francis.

Wulf, G., Töllner, T., & Shea, C. H. (2007). *Attentional focus effects as a function of task difficulty. Research Quarterly for Exercise and Sport, 78*(3), 257-264.

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