THE ROLE OF POSITIONAL ENVIRONMENTAL CUES IN MOVEMENT REGULATION OF YURCHENKO VAULTS IN GYMNASTICS

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Abstract

Numerous gymnastics skills demand a precise interaction between the gymnast and the environment. It remains unclear, how different environmental cues act and interact in the regulation of complex skills, such as Yurchenko-type vaults, where the gymnast performs a round-off before contacting the springboard. The aim of this study was to assess the roles of both, the position of the round-off mat and the position of the springboard, in the regulation of a Yurchenko timer. Kinematic parameters of eight female expert gymnasts' Yurchenko timers were examined in a baseline condition and two experimental conditions with different manipulations of the positions of the round-off mat and the springboard. Results revealed that visually controlled regulation of the run-up occurred in average two steps prior to the hurdle. Hand positioning on the round-off mat preceded a constant round-off flight phase. Gymnasts placed their feet on average on the same spot on the springboard, regardless of whether the springboard position was manipulated. Finally, hand positioning on the vault block mainly varied as a function of the position of the springboard and the distance of the flight phase to support. This study provides evidence that the position of the springboard regulates Yurchenko-type vaults. Knowledge about relationships between informational sources in the environment and the resulting motor behaviour in gymnasts may help coaches to develop training programs aiming to enhance gymnasts' ability to utilize this information in skill performance under changing environmental conditions in training and competition.

Keywords: *visual perception, task demands, yurchenko timer, kinematic analysis.*

INTRODUCTION

Complex gymnastics skills such as a Yurchenko on vault demand a precise interaction between the gymnast and the environment (Bradshaw, 2004; Kwon, Fortney, & Shin, 1990). In particular, gymnasts need to precisely hit the springboard and the vaulting table, in order to successfully perform the intended vault (Arkaev & Suchilin, 2004; George, 2010). To do so, gymnasts require access to perceptual information about themselves and their environment (Raab, de Oliveira, & Heinen, 2009; Warren, 2006). Utilizing visual information of particular environmental cues is thought to be of high importance in movement regulation of complex skills (Bradshaw, 2004; Fajen, Riley, & Turvey, 2008; Gautier, Thouvarecq, & Chollet, 2007; Warren, 2006). Nevertheless, the question arises, how different environmental cues act in the regulation of complex skills in gymnastics.

Perception-Action Coupling in Complex Gymnastics Skills

When a gymnast moves, he/she picks up information from the environment. This information is processed by different perceptual systems in their specific mode of operation (Vickers, 2007). The visual system processes for instance light that is reflected from the surrounding environment, and visual information contains the invariant features of the environment that gymnasts may utilize in movement regulation (Davids, Button, & Bennett, 2008; Gibson, 1979; Latash, 2008). The strong advantage of the visual system is that it enables the gymnast to pick up *distal* information, such as the position and structure of objects in the surrounding environment (Land, 2006; von Laßberg, Beykirch, Mohler, & Bülthoff, 2014). A gymnast might use this information in terms of an anticipatory control strategy to time and regulate his/her current action (i.e., run-up) to future events and event-related effects (i.e., placement of feet on springboard) in order to achieve a particular movement goal (Bardy & Laurent, 1998; Bradshaw, 2004; Hoffmann, Stoecker, & Kunde, 2004; Lee, Young, & Rewt, 1992; Turvey, 1992; Warren, 2006).

Gymnasts develop task-specific long-term memory representations during skill acquisition (Rosenbaum, Cohen, Jax, Van der Wel, & Weiss, 2007; Schack, Essig, Frank, & Koester, 2014). These representations contain information about relationships between intended motor behaviour/s and associated perceptual effects with regard to a particular movement goal (Latash, 1993; O'Regan & Noë, 2001; Prinz, 1997; Rosenbaum et al., 2007; Schack et al., 2014). In skilled gymnasts, these representations are thought to facilitate information pick-up and processing, because gymnasts better know *when* to utilize *which* information (Gegenfurtner, Lehtinen, & Säljö, 2011; Schack & Ritter, 2009). This in turn supports skill performance because skilled gymnasts attend to perceptual information that can be used directly and relied upon in movement regulation in order to achieve a particular movement goal (Montagne, Cornus, Glize, Quaine, & Laurent, 2000; Raab et al., 2009; Renshaw, Davids, Chow, & Shuttleworth, 2009; Schack, 2003; Withagen & Michaels, 2005).

Given the outlined theoretical perspective one could speculate that information derived from the structure of the vaulting apparatus, such as the perceived position of the round-off mat and the springboard, are likely to guide action in gymnastics vaulting because they might afford a precise interaction in order to perform the intended vault. Skilled gymnasts should therefore directly utilize this information when regulating action (Bradshaw, 2004; Heinen, Vinken, Jeraj, & Velentzas, 2013). Empirical evidence supporting this argumentation is summarized in the following paragraphs.

Movement Regulation in Gymnastics Vaulting

Meeuwsen and Magill (1987) could show that gymnasts' running kinematics differed when comparing the run-up for a handspring on vault (in which the task was to precisely hit a springboard in order to perform a reactive leap) with sprinting when no vaulting apparatus was present. The authors assessed several kinematic measures, such as stride length and stride duration. In particular, accuracy of feet placement on the springboard was related to the consistency of the stride length during the final part of the run-up and the hurdle. It was argued that visual information was utilized in the final part of the run-up (and the hurdle), indicating the use of visual information when the vaulting apparatus was present and when the task was to hit the springboard in order to perform a handspring. The results support the notion that gymnasts might use current perceptual information in terms of an anticipatory control strategy to time and regulate current action (i.e., feet placement during run-up) to future events (i.e., placement of feet on springboard) in order to perform an adequate handspring (i.e., Lee et al., 1992).

Bradshaw (2004) asked gymnasts to perform round-off entry vaults. Gymnasts' performances were videotaped and several kinematic parameters were analyzed from the videotaped performances. In particular, the onset of visual control was calculated from gymnasts' natural motor behaviour in the final part of the run-up. Results revealed that onset of visual control occurred in average two steps prior to the hurdle in Yurchenko-type vaults in gymnastics. In addition, the onset of visual control was related to parameters such as take-off velocity from the springboard, as well as post-flight distance of the vaults. This result highlights the functional role of visual information pickup during the run-up (and hurdle) for optimized skill performance in gymnastics vaulting (i.e., Raab et al., 2009).

Heinen, Jeraj, Thoeren, and Vinken (2011), as well as Heinen et al. (2013) asked gymnasts to perform handsprings on vault. The authors analyzed gymnasts' movement kinematics of the handspring vaults under different experimental conditions. In particular, the position of the springboard (Heinen et al., 2011), as well as the position of the springboard and/or the vaulting table (Heinen et al., 2013) were manipulated without gymnasts' awareness. Results revealed that a manipulation of the springboard position and the vaulting table position leads to predictable changes in movement kinematics during run-up (and other movement phases) of a handspring on vault. In the light of these findings one could argue that the (perceived) positions of the springboard and the vaulting table might be relevant informational cues when performing handsprings on vault (Heinen et al., 2011, 2013). The results support the notion that skilled gymnasts may attend to perceptual information that can be used directly and relied upon in movement regulation in order to achieve a particular movement goal (i.e., Withagen & Michaels, 2005).

Skilled gymnasts utilize visual information picked up from the environment in the regulation of complex skills. Empirical evidences support the notion that the positions of both, the springboard and the vaulting table seem to operate as relevant environmental cues in order to regulate handsprings on vault (Heinen et al., 2011, 2013). This however may be obvious particularly in handspring vaults because gymnasts' line of sight could in general be directed towards the vaulting apparatus during the entire run-up. Yet, the question arises to which degree the position of the springboard operates as an environmental cue to regulate Yurchenko-type vaults, where the gymnast performs a round-off before contacting the springboard (Bradshaw, 2004; Koh, Jennings, Elliott, & Lloyd, 2003). In addition, in Yurchenko-type vaults a round-off mat is placed in front of the springboard, and gymnasts place their hands on the mat during the round-off. Therefore, it could be questioned whether the position of the round-off mat additionally operates as a relevant informational cue in the regulation of Yurchenko-type vaults because the mat belongs to the structure of vaulting apparatus.

Given that both, the position of the round-off mat, and the position of the springboard could operate as relevant informational cues in the regulation of Yurchenko-type vaults, it was hypothesized that gymnasts place their hands on the same spot on the round-off mat, regardless of whether the round-off mat position was manipulated. It was furthermore hypothesized that gymnasts place their feet on average on the same spot on the springboard, regardless of whether the springboard position was manipulated (Heinen et al., 2011). There was no specific hypothesis on the effects of manipulating the position of the round-off mat and/or the springboard on positions of the hands during support on the vaulting block and we sought to explore this effect. Finally, distances of flight phases should vary as a result of changes in hand and/or feet placement and we also sought to explore this effect.

METHODS

Eight female gymnasts participated in this study (*age* = 13.9 ± 2.6 years; [mean ± standard deviation]). The gymnasts in this study could be characterized as experts because they reported to take part in National Championships with an average weekly training extent of 20.8 ± 3.3 hours and an average training experience in artistic gymnastics of 9.1 ± 2.5 years (Chi, 2006). The gymnasts were able to perform the experimental task of this study (Yurchenko timer; see Motor task paragraph) under changing environmental conditions (Davids et al., 2008).

Motor task. The motor task was a so-called Yurchenko timer (Arkaev & Suchilin, 2004; George, 2010; see Figure 1 for an illustration). Timers (as drills) are usually used in gymnastics training in order to develop the 'feel' of a complex skill without the need to complete the skill (Elliott & Mitchell, 1991; Turoff, 1991). The Yurchenko timer was used as experimental task in order to ensure gymnasts' safety, especially in experimental conditions where the positions of the round-off mat and the springboard were manipulated.

After a short run-up, the gymnast performs a hurdle jump followed by a round-off. In the round-off, the hands are placed on a round-off mat. The gymnast pushes herself off the round-off mat and places her feet on the springboard. The gymnast reactively leaps off the springboard with a backward rotation about her somersault axis performing a half back somersault. She engages a support position by placing her hands on a vault block. From this support position, she pushes off the vault block and rotates to landing on her back on a soft mat. A certified springboard (1.20 meters long, 0.60 meters wide) with a safety mat and a certified round-off mat were used (1.25 meters long, 1.00 meters wide). The height of the vault block was 0.80 meters with a width of 2.00 meters and a length of 1.00 meters. It was decided to use a vault block with a standard height of 0.80 meters, because it is typically used in methodical progressions in gymnastics, and therefore additionally supports gymnasts' safety when performing the Yurchenko timers in the experimental conditions.

Movement Analysis System. The kinematic parameters of the Yurchenko timers were analyzed by means of an optical movement analysis system. All performances were videotaped by using two full-HD video cameras with a spatial resolution of 1920 x 1280 pixels, and a temporal resolution of 50 Hz. The temporal measurement error was ± 0.02 seconds, and the spatial measurement error was ± 0.004 meters. The video cameras were placed orthogonal to the movement plane of the gymnasts. The first camera videotaped the run-up phase, and the second camera videotaped the hurdle movement and the Yurchenko timer. The field of view of both cameras overlapped by approximately two meters. Both cameras were placed 20 meters away from the movement plane of the gymnasts. The position of the toes at the beginning of the run-up, during each step of the run-up, and during the hurdle, as well as the position of the hands on the round-off mat, the position of the feet on the springboard during the reactive leap, and the position of the hands during support on the vault block were recorded using the software utilius® easyinspect (CCC-Software, 2008).

Measures. In order to assess movement regulation during the run-up, the hurdle, and the Yurchenko timer, the following six variables were calculated (see also Figure 1): (1) standard deviation in footfall position during each step of the run-up, and during the hurdle (Bradshaw, 2004; Lee, Lishman, & Thomson, 1982), (2) averaged distance of both hands to the leading edge of the round-off mat during the support phase of the round-off (average of s_{1st} and s_{2nd}), (3) distance of the toes to the leading edge of the springboard during take-off from the springboard in the Yurchenko timer (s_{feet}), and (4) distance of the hands to the leading edge of the vault block during the support phase of the Yurchenko timer (s_{hands}), (5) distance of the flight phase of the round-off ($s_{flight.1}$), and (6) distance of flight phase to support on vault block ($s_{flight.2}$). Kinematic parameters were averaged over all six trials for each gymnast in each study condition.

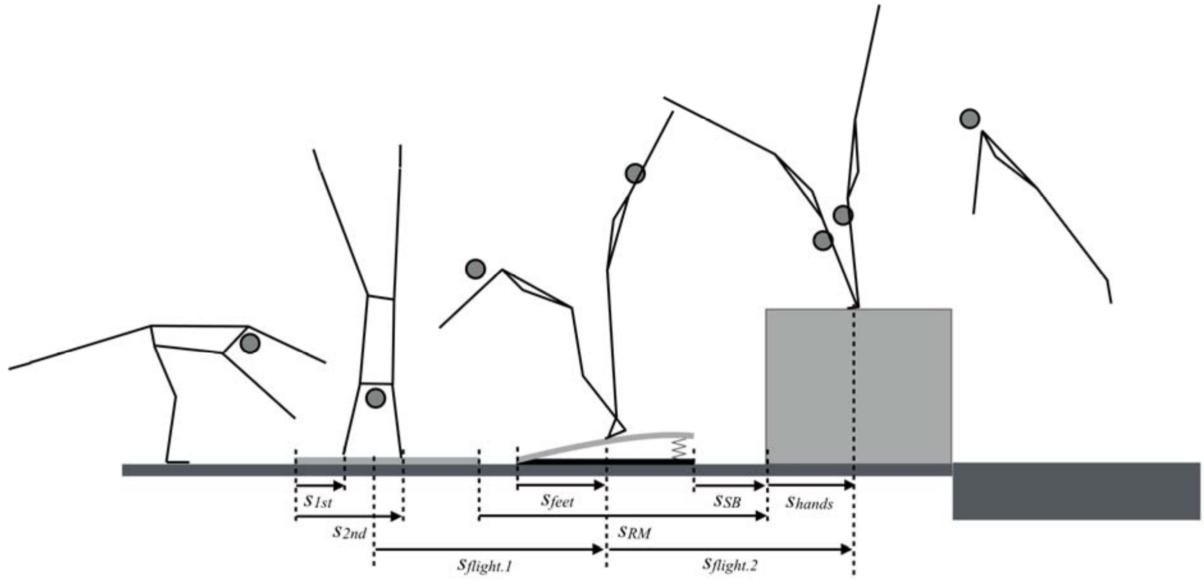

Figure 1. Stick-figure sequence of the experimental task (Yurchenko timer).

Note: s_{1st} and s_{2nd} denote distance of first and second hand to leading edge of round-off mat. s_{feet} is the distance of the toes to the leading edge of the springboard. s_{hands} indicates the distance of the hands to the leading edge of the vault block. s_{RM} and s_{SB} are the distance of the round-off mat and the distance of the springboard towards the leading edge of the vault block. $s_{flight.1}$ and $s_{flight.2}$ are the distances of the two flight phases.

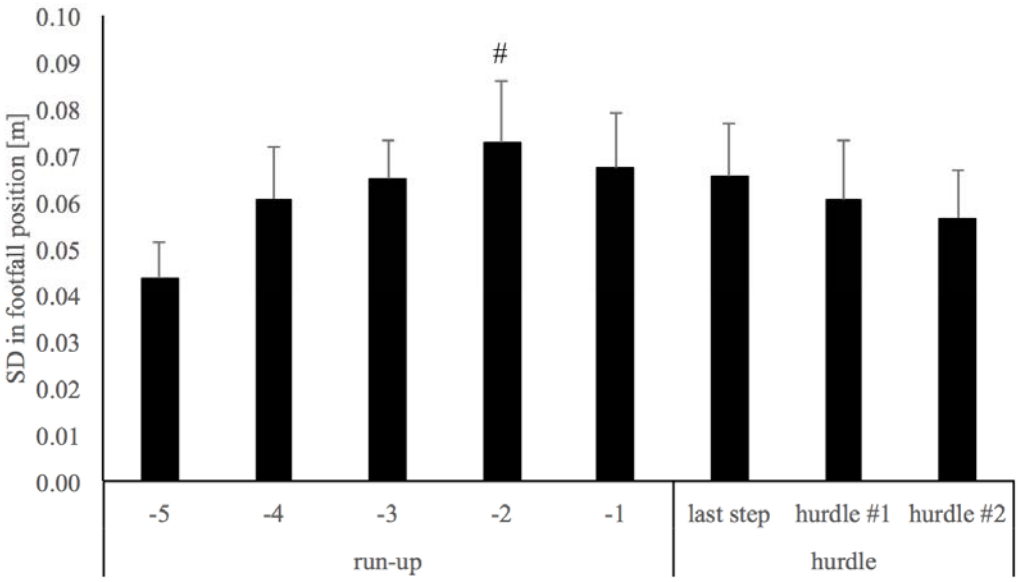

Figure 2. Standard deviations (SD) in footfall positions during the steps of the run-up, and during the hurdle movement (means ± standard deviations).

Note: The bars show aggregated values for all study conditions. The peak in standard deviation (#) occurred during the second last step prior to the hurdle movement, indicating the onset of visual regulation (Bradshaw, 2004).

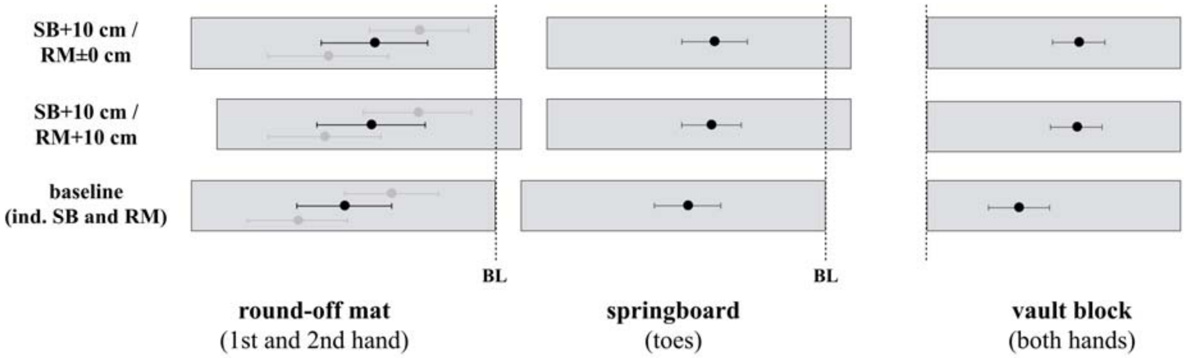

Figure 3. Illustration of the study conditions along with the means and standard deviations of (1) the averaged distance of both hands to leading edge of round-off mat during the support phase of the round-off, (2) the distance of the feet to the leading edge of springboard during the take-off phase of the Yurchenko timer, and (3) the distance of the hands to the leading edge of the vault block during the support phase of the Yurchenko timer.

Note: The baseline condition comprised gymnasts' individual distances of round-off mat and springboard to the vault block (BL = baseline, RM = round-off mat, SB = springboard).

The study was conducted in three phases. In the first phase the gymnast arrived at the gymnasium, and she was informed about the general procedure of the study. In particular, the gymnast was told that she takes part in a study on the kinematics of Yurchenko timers on vault. Contrary to the experimental approach in other studies (i.e., Heinen et al., 2011), the gymnasts were informed about the manipulation of both, the position of the springboard, and the position of the round-off mat. This was done to ensure gymnasts safety, because after placing the hands on the round-off mat, the gymnast moves and rotates backward with restricted vision to the springboard. Nevertheless, given that the gymnasts in this study could be characterized as experts, it was argued that regulation processes due to a manipulation of the round-off mat position, and the springboard position should operate, whether or not a gymnast is consciously aware of such a manipulation (Meeuwsen & Magill, 1987). The study was conducted in compliance with the Helsinki Declaration and the International Principles governing research on humans, as well as in line with the ethical guidelines of the local ethics committee.

The gymnast gave her written informed consent, and she was given a 20-minute warm-up period. After warm-up, the gymnast was allowed three familiarization trials. In the familiarization trials, the round-off mat and the springboard were placed at gymnasts' individual distances thereby reflecting the baseline condition. In the second phase, the gymnast performed 18 Yurchenko timers, six in each experimental condition, and six in the baseline condition. The gymnasts began with the baseline trials. The remaining 12 trials of the two experimental conditions were presented in a randomized order. An instructed experimenter placed the springboard and/or the round-off mat according to the individual experimental protocol for each gymnast. Prior to each trial, the gymnast was informed about the experimental manipulation. Each gymnast was allowed to take breaks as requested and there was no time pressure. In the third phase, and after completing the 18 Yurchenko timers, the gymnast was given an individual cool-down period, she was debriefed, and received a gift as reward for participation in this study.

As significance criterion $\alpha = 5\%$ was defined a-priori. Gymnasts exhibited in average five run-up steps in each of the experimental conditions, and in the baseline condition. The standard deviation method was applied in order to evaluate standard deviations in footfall position during each step of the run-up and during the hurdle (Bradshaw, 2004; Lee et al., 1982). In order to assess the influence of a manipulation of both, the positions of the round-off mat and the springboard on the dependent variables, separate Wilcoxon matched pairs tests were calculated between the baseline condition and each experimental condition.

RESULTS

Onset of visual control was expected to take place two steps prior to the hurdle, independent of the experimental condition (Bradshaw, 2004). It was hypothesized that gymnasts place their hands on the same spot on the round-off mat, regardless of whether the round-off mat position was manipulated. It was furthermore hypothesized that gymnasts place their feet on average on the same spot on the springboard, regardless of whether the springboard position was manipulated. There was no specific hypothesis on the effects of manipulating the position of the round-off mat and/or the springboard on positions of the hands during support on the vaulting block and we sought to explore this effect. Finally, distances of flight phases should vary as a result of changes in hand and/or feet placement and we also sought to explore this effect.

Peak in standard deviation in footfall position during run-up could be identified in the second last step prior to the hurdle in the baseline condition as well as in the experimental conditions. Comparing the baseline condition with experimental conditions, revealed neither statistically significant differences in standard deviations in footfall positions in the run-up, nor in the hurdle (all p > .05). Figure 2 thus illustrates the aggregated values for the experimental conditions and for the baseline condition.

In the baseline condition, gymnasts placed their hands 0.60 ± 0.19 metres from the leading edge of the round-off mat during the support phase of the round-off. The toes were placed 0.65 ± 0.13 metres from the leading edge of the springboard during the reactive leap, and the hands were placed 0.36 ± 0.12 metres from the leading edge of the vault block during support on the vault block. The distance of the round-off flight phase was 1.35 ± 0.09 metres, and the distance of the flight phase from reactive leap to support on the vault block was 1.31 ± 0.11 metres (see Table 1 for details).

When both, the springboard and the round-off mat were placed 10 centimetres closer to the vault block (SB+10 cm / RM+10 cm condition), the following pattern of results emerged: Gymnasts placed their hands in average on the same spot on the round-off mat (Z = 0.56, p = .57). They also placed their feet on average on the same spot on the springboard (Z = 0.14, p = .89). However, distance of the hands during support on the vault block was in average 0.23 metres longer compared to the baseline condition (Z = 2.52, p = .01). The distance of the round-off flight phase was not significantly different from the baseline condition (Z = .28, p = .78), whereas the distance of the flight phase to support on the vault block was 0.13 metres longer compared to the baseline condition (Z = 2.52, p = .01, see Figure 3 for an illustration).

When the springboard was placed ten centimetres closer to the vault block, and the round-off mat was placed at baseline position (SB+10 cm / RM±0 cm condition), the following pattern of results emerged: Gymnasts placed their hands 12 centimetres closer to the back edge of the round-off mat (Z = 2.52, p = .01). They placed their feet on average on the same spot on the springboard (Z = 0.14, p = .89). However, distance of the hands during support on the vault block was in average 0.24 metres longer compared to the baseline condition (Z = 2.52, p = .01). Distance of round-off flight phase was the same as in the baseline condition (Z = 1.40, p = .16), and distance of flight phase to support on the vault block was 0.14 metres longer compared to the baseline condition (Z = 2.24, p = .03).

DISCUSSION

Results revealed that when performing Yurchenko timers, the onset of visual control occurred in the run-up, two steps prior to the hurdle. Hand positioning on the round-off mat preceded a rather constant round-off flight phase. Gymnasts placed their feet on average on the same spot on the springboard, regardless of whether the springboard position was manipulated. Hand positioning on the vault block mainly varied as a function of the springboard position and the distance of the flight phase to support. If we summarize the results of the study, it becomes apparent that female expert gymnasts predominantly use the springboard as informational source to regulate Yurchenko timers on vault. Onset of visual control inferred from standard deviation in footfall position occurred in average two steps prior to the hurdle in all study conditions, thus indicating that the perception of environmental cues is likely to take place in the last part of the run-up, prior to the hurdle. This result supports the notion of an anticipatory control strategy to time and regulate current action (i.e., run-up) to future events and event-related effects (i.e., placement of feet on springboard; Bardy & Laurent, 1998; Hoffmann et al., 2004;

Turvey, 1992). Gymnasts seem to anticipate the reactive leap from the springboard already prior to the round-off, and they regulate the run-up accordingly. This result is in line with findings of Bradshaw (2004) and Meeuwsen and Magill (1987). However, comparing the results of the current study with the results of other studies (e.g., Heinen, Artmann, Brinker, & Nicolaus, 2015), one could argue that onset of visual regulation might be (to some degree) task-dependent (see also Bradshaw, 2004). Theories of visual and attentional expertise suggest that it is not only important *which* informational cues are used in movement regulation but also *when* these cues are used (Gegenfurtner et al., 2011; Land, 2006). It seems that skilled gymnasts possess specific memory representations so that they know at which distance they need to pick up which information in order to regulate the run-up with the aim of a precise interaction with the vaulting apparatus during complex skills, such as a Yurchenko timer.

The round-off mat does not seem to be a strong cue on movement regulation in the performance of the Yurchenko timers. For instance, gymnasts have to place their feet on a particular area on the springboard in order to achieve optimum recoil during take-off, given the elastic properties of the springboard (Čuk & Karacsony, 2004). The elasticity of the round-off mat, however, is rather equally distributed, and there is in general no necessity to place the hands on a particular spot on the round-off mat (as long as there is enough space left; George, 2010). This argumentation receives support from a comparison of gymnasts' motor behaviour in the experimental conditions, and in the baseline condition. One may speculate that performing a rather constant round-off flight phase could be one important strategy in the performance of Yurchenko timers, as long as there is enough space left on the round-off mat to place one's hands during the round-off.

Table 1
Gymnasts' kinematic parameters (means ± standard deviations) of the Yurchenko timers on vault in the two experimental conditions, and in the baseline condition.

Variables	Baseline (ind. SB and RM)	Conditions SB+10 cm / RM+10 cm	SB+10 cm / RM±0 cm
s1st2nd [m]	0.60 ± 0.19	0.61 ± 0.21	0.72 ± 0.21*
sfeet [m]	0.65 ± 0.13	0.65 ± 0.12	0.65 ± 0.14
shands [m]	0.36 ± 0.12	0.59 ± 0.10*	0.60 ± 0.10*
sflight.1 [m]	1.35 ± 0.09	1.34 ± 0.12	1.33 ± 0.09
sflight.2 [m]	1.31 ± 0.11	1.44 ± 0.11*	1.45 ± 0.12*

Note: * denotes statistical significant difference ($p < .05$) between the particular experimental condition, and the baseline condition (RM = round-off mat, SB = springboard).

Onset of visual control inferred from standard deviation in footfall position occurred in average two steps prior to the hurdle in all study conditions, thus indicating that the perception of environmental cues is likely to take place in the last part of the run-up, prior to the hurdle. This result supports the notion of an anticipatory control strategy to time and regulate current action (i.e., run-up) to future events and event-related effects (i.e., placement of feet on springboard; Bardy & Laurent, 1998; Hoffmann et al., 2004; Turvey, 1992). Gymnasts seem to anticipate the reactive leap from the springboard already prior to the round-off, and they regulate the run-up accordingly. This result is in line with findings of Bradshaw (2004) and Meeuwsen and Magill (1987). However, comparing the results of the current study with the results of other studies (e.g., Heinen, Artmann, Brinker, & Nicolaus, 2015), one could argue that onset of visual regulation might be (to some degree) task-dependent (see also Bradshaw, 2004). Theories of visual and attentional expertise suggest that it is not only important which informational cues are used in movement regulation but also when these cues are used (Gegenfurtner et al., 2011; Land, 2006). It seems that skilled gymnasts possess specific memory representations so that they know at which distance they need to pick up which information in order to regulate the run-up with the aim of a precise interaction with the vaulting apparatus during complex skills, such as a Yurchenko timer.

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At the same time, however, the springboard seems to be a more important cue when performing Yurchenko timers compared to the round-off mat. Gymnasts placed their feet on average on the same spot on the springboard, regardless of whether the springboard position was manipulated. This result is consistent with findings of Heinen et al. (2011, 2013), thereby supporting the notion that the position of the springboard operates as informational source to regulate Yurchenko timers on vault. Even if gymnasts are unable to "see" the springboard position during the second part of the round-off (when their back is facing the springboard, and thus their line of sight is directed away from the springboard) it seems plausible that they perceive the position of the springboard during the (last part of the) run-up, thereby again supporting the idea of an anticipatory control, thus enabling the gymnasts to precisely hit the springboard at the end of the round-off. One could argue that gymnasts compare the position of the springboard with their long-term memory representation of the movement, and the appropriate places of the springboard. In addition, in both of the experimental conditions the springboard was placed closer to the vault block, thus affording a slightly longer run-up, which may have resulted in a slightly more dynamic round-off, which in turn resulted in a longer flight phase to support on the vault block.

There are several limitations of the study which should be highlighted. First, the position of the springboard and the round-off mat were manipulated in steps of ten centimetres. One could argue that a stronger manipulation could lead to different effects on movement regulation of the Yurchenko timer. It could for instance be of interest to assess the relationship between the strength of manipulating positional environmental cues and gymnasts' regulation capacity when dealing with these manipulations.

Second, gymnasts were informed about the manipulation of both, the position of the springboard, and the position of the round-off mat mainly for safety reasons. However, one cannot be sure whether this information influenced the results of this study. Prior knowledge about the experimental manipulation could lead to a different anticipation process and therefore to a different motor behaviour. Nevertheless, it is suggested to investigate the influence of prior information on gymnastics tasks incorporating restricted vision with less environmental constraints, such as round-off, back handspring and back somersault on floor, where the primary aim is not to precisely hit a springboard, but rather to land inside the limited area of the floor apparatus.

Third, expert gymnasts are thought to be already attuned to task-relevant informational sources (Raab et al., 2009). The question, however, could be how the role of informational cues change over the process of motor skill acquisition. While it may be helpful for a novice gymnast to use the round-off mat as a relevant cue when performing the round-off (in order to acquire an adequate round-off technique with a constant flight phase and thus to prevent ‘flying over’ the springboard), the round-off mat may not be a relevant cue any more for an expert gymnast because he/she already acquired an adequate round-off technique. A subsequent study should thus assess the role of the round-off mat as an informational cue for novices’ motor behaviour in Yurchenko timers.

There are, however, some practical consequences and implications that can be concluded from the current study. Gymnastics involves numerous skills with unique technical requirements (Sands, Caine, & Borms, 2003). Therefore, for gymnasts an adaption to varying conditions is essential, not only regarding different task requirements but also regarding physical and psychological changes between training and competition. It could therefore be fruitful for the learner to practice Yurchenko-type vaults under varying conditions, and with varying movement patterns in order to develop a broad range of regulation strategies. This could easily be achieved by practicing Yurchenko-type vaults with different run-up lengths, as well as with different positions and distances between the round-off mat, the springboard, and the vaulting table. A particular emphasis should be placed on the acquisition of adequate movement technique of the round-off (i.e., optimum flight phase; see also Bradshaw, 2004, for further ideas). Applying a *differential learning approach* (Schöllhorn, Hegen, & Davids, 2012) might support the development of functional movement strategies together with its corresponding long-term memory representations especially in complex tasks, such as a Yurchenko on vault. It is thus important for the gymnast to engage in a functional between-trial processing because this may support long-term memory formation and retention (Schack & Ritter, 2009; Schöllhorn et al., 2012). This might also help to overcome potential problems related to practice specificity and context dependence (Keetch, Lee, & Schmidt, 2008; Schmidt, Young, Swinnen, & Shapiro, 1989).

This study provides evidence that the position of the springboard regulates Yurchenko-type vaults in female expert gymnasts. Knowledge about relationships between informational sources in the environment and the resulting motor behaviour in gymnasts may help coaches to develop training programs aiming to enhance gymnasts’ ability to use visual information during the approach run and to regulate their movements under changing environmental conditions in training and competition.

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