Using rhythmicity to promote performance in horizontal jumps

Citation for published version:
Macpherson, AC, Collins, D, Graham-Smith, P & Turner, AP 2013, 'Using rhythmicity to promote performance in horizontal jumps: An exemplar of the need for individually-tailored interventions', *International Journal of Sport Psychology*, vol. 44, no. 2, pp. 93-110.
https://doi.org/10.7352/IJSP.2013.44.093

Digital Object Identifier (DOI):
10.7352/IJSP.2013.44.093

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Peer reviewed version

Published In:
International Journal of Sport Psychology

Running head: RHYTHMICITY AND HJ PERFORMANCE

Using Rhythmicity to Promote Performance in Horizontal Jumps: An Exemplar of the Need for Individually-Tailored Interventions

Alan. C. MacPherson

University of Edinburgh, Edinburgh

Dave Collins

University of Central Lancashire, Preston

Phil Graham-Smith

University of Salford, Salford

Anthony. P. Turner

University of Edinburgh, Edinburgh

2nd Revision - paper submitted: 12th November 2012

Correspondence concerning this article should be addressed to Alan MacPherson at: Institute for Sport, Physical Education and Health Studies, The University of Edinburgh, St. Leonard's Land, Holyrood Road, Edinburgh. EH8 8AQ.

Tel: 0131 651 6647

E-mail: alan.macpherson@ed.ac.uk

Abstract

The current study compared and contrasted the optimal regulation of stride patterns in the horizontal jumping events for 6 British athletes of international standard. Long jump and triple jump approach data were collected over a 3-year period in international and domestic competitions and considered against the distances achieved. Results suggest that on approach to the take-off board, the majority of athletes’ jumps of greater length (intra-athlete) are associated with a low variability, rhythmical footfall. Given the variable approach strategies used by the athletes in question, and consequently the theoretical implications the data set holds, tentative conclusions are drawn regarding the means by which scientists and coaches should assess and design suitable performance focused interventions for elite performers based on individual responses.

Using Rhythmicity to Promote Performance in Horizontal Jumps: An Exemplar of the Need for Individually-Tailored Interventions

Determining how skilled performers execute goal-directed behaviours and the means that enable performance to be enhanced is an essential role which applied sport psychologists often conduct in partnership with other scientists. In doing so, scientist-practitioners often seek guidance from the prevailing theoretical and/or empirical paradigms before applying this knowledge to the practical problem at hand. However, this may sometimes take thinking in an erroneous or less than optimum direction, especially in the special cases of elite performers. In this regard, recent evidence suggests that there are significant advantages to examining how skilled performers organise movement patterns on an intra-individual basis, despite commonalities in patterns of co-ordination being evident in participants of similar ability. For example, Chow, Davids, Button, and Koh, (2006) stated that if skilled participants are grouped together for the purposes of movement analysis, effects of interest, such as control strategies may become masked.

Support for pursuing applied sport psychology on a case-by-case basis is illustrated by an increasing number of studies that demonstrated individual-specific findings with reference to performers' coordination, their responses to appropriate sources of information for instruction and adaptation to physical stress. For example, Beavan, Gill, and Cook (2008a) demonstrated that professional rugby union players with broadly similar training backgrounds responded to group-prescribed resistance training through individual hormonal responses. It was determined that certain players responded positively to some training stresses, but not to other forms of resistance training. In a 3-week cross-over design, the same players alternated between sessions that produced high and low levels of testosterone. It was found that favoured exercise selection elicited players' maximum testosterone response and resulted in a statistically significant strength gain. However, when the less favoured protocol was used, there was either no change, or a significant decline in tested strength (Beavan, Gill, & Cook, 2008b). Such individualised hormonal responses to training adaptations in professional sport lend credence to the claim that advanced performers should be investigated on an individual basis.

Further support for this contention is provided by examples of empirical research that advocated the application of generic instructional principles to elite groups with—in some cases—less than optimum results. Research carried out with shooters (e.g., rifle, pistol, and archery) by Helin, Sihvonen, and Hanninen, (1987) and Landers, Christina, Hatfield, Daniels and Doyle (1980) suggested that shooters performed to an optimised level when they shot in-between heartbeats when the cardiac cycle is in diastole, or in what is termed the inter-beat interval (IBI). However, analysis of case study data of six elite-level shooters conducted by Bellamy, Collins, Holmes and Loze (1999) indicated that there is insufficient evidence to advocate a *universal* strategy of shooting during diastole in elite shooters, since four of the six shooters examined actually shot on the beat. Rather, they suggested the essential need for checks that could detect individual patterns associated with better performance. Whilst this example is somewhat dated, it is uncertain whether the application of generic instructions to elite or advanced performers, albeit derived from peer-reviewed empirical work would automatically result in an improvement to personal performance.

A more recent example of the contrasting instructional content of pre-performance routines (PPRs) among elite golfers (i.e., mean handicap of +1.5) was uncovered by Cotterrill, Sanders, and Collins (2010). Whilst the content and firing modality of PPRs has been well researched in relation to self-paced skills (Singer, 2002), research conducted by Cotterrill et al. (2010) showed that the development of a PPR for an elite golfer is idiosyncratic; contingent upon their coping resources; factors that constitute their personalities; and a tendency to appraise the context of each golf shot prior to task execution.

Accordingly, we suggest that working uncritically from theory to intervention is not an appropriate strategy for groups of advanced learners.

In light of these two examples (shooting & golf), it is important to reflect upon the work of Newell, Liu, and Mayer-Kress (2005). Specifically, they proposed that different types of information are differentially effective for athletes, and that the efficacy of alternative sources of information is dependent on the task and the skill level of the learner. Consequently, it is unlikely that an athlete's potential will be maximised if a 'one instruction fits all' approach is used. Therefore, the onus is on applied scientists to determine the most effective sources of information to communicate with and inform athletes' motor systems. For example, in a study that provided concurrent auditory feedback to gymnasts on the pommel horse, body segment alignment improved by 2.3% between the experimental and control groups. Researchers concluded that auditory feedback provided in real-time could be used to correct complex movements (Baudry, Leroy, Thouvarecq, & Chollet, 2006) as opposed to the more commonly applied video techniques. Interestingly, anecdotal evidence suggested that experienced horizontal jumps coaches could listen to the footfall of their athletes, whilst looking in the opposite direction, and were able to confidently assert whether their athlete had jumped well, or not (Moore, 2006).

Whilst it seems that some horizontal jumps coaches have become aware of, and utilise, the rhythm engendered by the auditory output of an athlete's footfall signature on approach to the take-off board, there is interesting empirical research that has demonstrated the beneficial effect of utilising an auditory output to augment visual information. In a complex series of five experiments Vroomen and de Gelder (2000) demonstrated that perceptual organisation in the auditory modality impacted upon perceptual accuracy in the visual modality. Specifically, a high tone embedded in a series of low tones improved detection of a visual target, when the visual target was presented at the same time – provided that the tone was abrupt and distinct from background noise or contaminating melodies. These studies demonstrated that auditory stimuli can be used to enhance the detection of visual information. Therefore, it is possible that a holistic rhythm of an athlete's footfall prior to contact with the take-off board may serve as an aid to improve foot-to-board accuracy – provided an athlete's footfall patterns are deemed to be relatively stable.

Whilst some athletes might not find this modality of movement correction useful, data presented in this paper provide an opportunity for scientists, applied practitioners, and coaches to consider the implications of working with elite performers through an exemplar of this 'individualised' approach. Specifically, the applicability of prevailing theoretical paradigms pertaining to the approach and preparation phases of horizontal jumps is critiqued through consideration of data obtained from a cohort of elite performers.

Horizontal Jumps: Event demands

For athletes participating in horizontal jumps (HJ) the apparent difficulty associated with executing the task lies in direct contrast to the simplicity of the objective. In particular, the challenge rests in the trade-off between maintaining peak horizontal velocity (athletes typically achieve peak horizontal velocities at take-off of 9.4 m/s for men, and 8.6 m/s for women; see Linthorne, 2007) and being accurate on to the take-off board. To maximise the measured distance, the space between the jump take-off and the edge of the take-off board must be minimised. In addition, the athlete is required to create good 'lift' at take-off, generating vertical impulse by accelerating body parts upwards during the final contact with the board without employing large braking forces. A key factor in generating vertical lift is the transference of horizontal velocity accrued on the run-up. Therefore, accuracy onto the take-off board, at speed, is critical to eventual distance achieved (Hay, Miller, & Canterna, 1986).

At an elite level the difficulty of “hitting the board” in HJ is exemplified by 1 participant in this investigation, an elite horizontal jumper, who had 10 years of competitive experience and had medalled in major international competition. Yet, over a 3-year period this athlete had “no jumped” in 48% of attempts (Athlete 3, table 1). Whilst this inconsistent pattern may be atypical when contrasted with other athletes, in general, the automaticity of the movement and the accuracy of the visuo-perceptual approach utilised must be subject to scrutiny if task execution is to be enhanced, and individual performance potential is to be realised.

Selecting theoretical perspectives for guidance.

Ecological psychologists have long been concerned with determining the relationship between perceiving and acting (Gibson & Pick, 2000). An important variable used to investigate interceptive timing was tau, or time-to-contact (Lee, Lishman, & Thomson, 1982). Latterly, studies investigating perceptual control mechanisms relevant to the approach phase in horizontal jumps have emphasised the role of perception-action coupling (Warren, 1988). The reason underlying this theoretical succession is based upon the empirical finding that perception-action coupling occurs throughout the approach phase to the take-off board this being quite distinct from tau: The data that underpins the time to contact (tau) stipulates that visual regulation corrects the accrued approach phase error at a specific point in the run-up; at about four strides from the take-off board.

However, according to Montagne et al. (2000, p.38), “a control mechanism based upon perception-action coupling will not produce systematic changes of the step length unless the need for adjustment is perceived.” Therefore, if alterations to gait are required to intercept a target, the utilisation of perception-action coupling would engender a continual measured response which is prospective and thus allows movements to be instantly adapted to changes in perceptual information (Montagne et al., 2000; see Renshaw & Davids, 2006), thus enabling the athlete to meet the take-off board. Whilst instructive, the sample used in the Montagne et al. (2000) study were not athletes; rather, they were volunteer undergraduate students who were instructed to take a set number of strides to the board.

More recently, research specific to high performance that investigated the role that expertise plays in the visual regulation of perceptual guidance was conducted by Renshaw and Davids (2004). In a study investigating the footfall pattern of professional cricket bowlers, results indicated that bowlers made adjustments to their gait throughout their approach to the crease, thus lending further empirical support to the role of perception-action coupling in interceptive, self-paced tasks. A secondary, though no less interesting finding, showed that between-participant variability was high. Therefore, it can be concluded that variability in the application and implication/effect of individuals' perceptual control mechanisms are a feature of studying motor control; as such, it follows that participants in different sports are likely to possess appreciably different solutions to the constraints that differing tasks pose.

A further interesting study that contrasted cricket bowlers' and long jumpers' respective run-ups was conducted by Renshaw and Davids (2006). It was determined that the bowlers, in contrast to the long jumpers, demonstrated a lower gait variability that allowed them to develop "a stable, rhythmic movement pattern at a controlled velocity" (Renshaw & Davids, 2006, p. 16). Given the apparent similarity in prescribed movement patterns in each discipline (i.e., running fast to hit a prescribed point then execute a high power action), there is the potential for horizontal jumpers, provided they can control horizontal velocity, to demonstrate a rhythmic movement pattern in the approach phase that might be associated with better performances, or indeed – the employment of prospective perception-action coupling. At the very least, reflecting our earlier comments on the need for individualisation, patterns should be checked against performance to see if a central movement and/or perceptual control strategy can be linked to a complementary source of information that may, in the case of specific athletes, promote a positive performance outcome.

On the board accuracy: An alternative perspective – ‘rhythmicity’?

As expertise increases, variability decreases – but it persists, nonetheless. Given this constant, it is instructive to reflect upon what Buekers (2000, p. 487) states; namely, as an athlete gathers expertise, a shift in emphasis occurs; in essence, skilled movement execution progresses from “variation in variable situations, to variation in specific situations”. Therefore, a task for coaches working with an elite jumper is to seek to determine optimal sources of perceptual guidance through which on-the-board accuracy can be made consistent. In a review of research into interceptive timing tasks, Savelsbergh and Van der Kamp (2000) state that multiple sources of information result in different timing strategies. Importantly, they concluded that the ability to use and exploit different sources of information allows performers to adapt to different circumstances. Therefore, given that movement variability is a persistent factor, providing athletes with the opportunity to experience alternative sources of information would seem to be evidence of good coaching practice.

One such source of information that may promote on-the-board accuracy at speed is rhythmicity: Rhythmicity can be defined as a temporal *pattern* apparent in a movement, or set of movements, whose constituent parts are relatively stable (MacPherson, Collins, & Obhi, 2009). In this way, rhythmicity is similar to the observed preservation of relative timing in the execution of movement components in a sequence (e.g., Schmidt & Lee, 1999). In fact, such internal rhythmicity may be an important characteristic of better performers. For example, practiced joggers strive to maintain a stable relationship between their rates of respiration and stride pattern (Beek, Jacobs, Daffertshofer, & Huys, 2003). Therefore, it seems that humans possess an innate (Szirmai, 2010), though perturbable (MacPherson, Turner, & Collins, 2007) sense of rhythm that is associated with their level of expertise (MacPherson, Collins, & Morriss, 2008).

Furthermore, rhythmicity is not restricted to unconscious processing: It has been demonstrated that a mental focus attenuated to the temporal rhythm (footfall) associated with the execution of a javelin throw resulted in lower movement variability in key joint angles when contrasted to javelin throwers whose respective mental foci were attenuated upon a sub-routine of the throwing action (MacPherson et al., 2008). Similarly, Agostini, Righi, Galmonte, and Bruno (2003) used an auditory rhythmical cue to improve throwing consistency in an international hammer thrower. Therefore, it may be that humans organise movements to optimise consistency as well as seeking to decrease the effects of accumulated perceptual error.

Reflecting these considerations, and against the overarching agenda of performance enhancement, two purposes were served by the present investigation: (a) we wished to determine the optimal means of regulating footfall patterns in horizontal jumps, and (b) we wanted to consider the data from these elite individuals against established empirical advice proffered in the literature— referring specifically to the role of perception-action coupling— as a feature of our search for effective interventions as psychologists and sport scientists.

Method

Participants

Six full-time international athletes agreed to have their footfall patterns analysed from video recordings of International Grand Prix events and AAA UK domestic trials. The cohort comprised four long jumpers and two triple jumpers. All of the athletes in question were based in the UK and had competed and medalled in major international competition. At the time of writing, all were currently, or had recently been ranked among the top eight in the world.

Collection of data

The run-up phase of the HJ was recorded using a digital camcorder (Canon XM1; Tokyo, Japan) operating at 25 frames per second with a 1/250 second shutter speed. Quintic Biomechanics software (Coventry, UK) was used to de-interlace the video footage and increase the footage to 50 fields per second with a 1/500 second shutter speed; therefore, time-of-foot contacts were obtained to the nearest 0.02 s – an identical rate of film capture to that used by Renshaw and Davids (2004). The camera panned through the full approach but a complete set of data was captured for all of the athletes for the final 15, uninterrupted strides to the board.

Analysis

In keeping with the previously established research on approach strategies in horizontal jumps (Lee et al., 1982), we used standard error (SE) of footfall variation. The intra-athlete SE was collated by digitising the first footfall contact with the track 15 strides prior to contact with the board, and for each footfall contact in-between. The analysis window covered the time taken to travel fifteen strides to the take-off board with the timing of each foot contact recorded for analysis of variability. The athlete's pattern of footfall variation (PFV) was analysed by taking the SE for each contact point. The timing of each foot contact was taken relative to the final contact with the take-off board. It was then possible to plot the PFV for each athlete (see Figures 1-6 and Table 1). Data collection ceased when the athlete's foot struck the take-off board. In addition to PFV, the length of each legal jump for all of the athletes was also recorded.

In the present study, athletes' jumps were divided according to performance into upper quartile (UQ) and lower quartile (LQ) - intra-athlete. Overall, given the unrepresentative nature of this population and the fact that they cannot, by definition, be considered a representative sample, a limited inferential statistical analysis was conducted - intra-athlete. Paired t-tests were conducted for each athlete comparing the PFV associated with their jumps in the UQ and LQ. In addition, effect sizes are presented where statistical significance was determined.

In the present study the dependent measure was time (s) as opposed to distance from the board (cm). This difference in protocol was due to track markers being illegal in IAAF meetings. Furthermore, in the present study and as per normal practice, the distance that the athletes started their approach to the board varied in, and between competitions. This variation was in part due to their performance, but was also influenced ‘jump-by-jump’ by environmental constraints (e.g., temperature, precipitation, wind speed and track type).

In the present study it was considered that if a high level SE prior to and upon contact with the take-off board was evident, then participants could not be considered to be utilising a rhythmical footfall strategy. Furthermore, it should be noted that the data collection used in this study reflects the ‘real-life’ challenge which such athletes face in that the start point of the run-up was varied to ensure optimum on-the-board contact. In terms of scientific control this situation is less than optimal, however the approach used represents an accurate, ecologically valid depiction of the task constraints experienced by the athletes in question.

Reliability of observations

The first author of the present paper carried out the data analysis; however, to determine the typical error (Hopkins, 2001) associated with the analysis of PFV, it was necessary to calculate the accuracy of observations made (i.e., inter-rater reliability). Four approaches were extracted (fifteen strides from the board – Athlete 1) from the upper quartile jumped and data contrasted with a second individual skilled in this type of data analysis. Results indicated that typical error (i.e., inter-rater test re-test reliability) was r =.98, a figure deemed to be acceptable by Clarke-Carter (2001), and well in excess of the minimum agreed level of $r = 0.8$ as stipulated by Kline (1993).

Results

PFV (pattern of footfall variation) was utilised to determine the consistency of stride pattern from 15 strides out, to contact with the take-off board. Results have been organised to provide a contrast in PFV when athletes jump greater and lesser distances. Given the idiosyncratic nature of the data, analysis was conducted intra-athlete, on a case-by-case basis.

Insert Table 1 here

As can be seen from Table 1, the number of jumps that form the quartiles for each athlete differs. This is in part due to all manner of constraints outside the researchers' control. However, the distances obtained reflect ecologically significant differences in outcome. In each case, the upper quartile of distances achieved by this cohort of athletes would likely result in their inclusion in the final of most European, and certainly, national athletics events. For example, as of October 1st, 2012, the world's best performances in Men's long jump, Women's long jump and Men's triple jump, were: 8.35 m; 7.15 m; and 17.81 m, respectively. Therefore, the distances achieved in the upper quartile by the cohort of athletes in this study, although not World leading, would enable them to put pressure on the other athletes they were competing against.

Low levels of PFV in the UQ of distance jumped are evident in the variability profiles of four athletes (Figures 1, 2, 4, and 5). This suggests that these athletes are capable of jumping greater distances when there is a more consistent (low variability) PFV.

Insert all Figures here

The pattern of variability in athletes 1, 2, 4 & 5 was sufficient for there to be a statistically significant difference between the upper and lower quartiles (see table 2). Moreover, the moderate to large effect sizes (see table 2) calculated for these athletes demonstrate that the standardised difference in their respective means between the upper and lower quartile are of note. No statistically significant differences were found between the UQ and LQ for athletes 3 & 6.

Insert table 2 here

However, in the case of Athlete 3, low levels of PFV are apparent (see figure 3) in the UQ, but not to an appreciable, or statistically significant, extent when contrasted to the LQ - although the last five strides provide further limited support. Additional support for the contention was not found in regard to athlete 6, who exhibited idiosyncratic PFV plots unlike any other athlete which bore no relation to any empirically derived perceptual programming techniques reported in the current literature. Yet, upon observation of both quartiles for Athlete 6, the PFV values are relatively low when contrasted to the PFV levels of the other participants recorded in the UQ. Therefore, the data recorded for this Athlete 6 (in both categories) may be interpreted as an example of already low PFV levels contributing toward an effective runway strategy where horizontal velocity is not diminished by braking to enable foot-placement behind the take-off board.

Discussion

We present no data that demonstrate cause and effect, although against the primary, applied purpose of the work, a number of interesting trends were observed. A clear pattern of data suggested less variation in the PFV when 4 athletes in the present study jumped greater distances (demonstrated in Figures 1, 2, 4 & 5); moreover, statistically significant differences were apparent among these athletes' UQ and LQ. These findings were not manifested in the approach patterns of Athletes 3 and 6. To clarify, in the majority of athletes examined we have observed an association between increased distances jumped and lowered levels of footfall variability – intra-athlete, and low, but idiosyncratic PFV plots in relation to Athlete 6. However, from the data collected, it cannot be definitively stated what perceptual factors caused the athletes in question to achieve greater distances; only, that performance was, in the majority of cases, associated with lowered levels of PFV. In light of the results presented, there are two overarching issues to be considered: (a) The implications of working with elite athletes on a case-by case basis, and (b) Using rhythmicity as our frame of reference, the specific implications for performers, coaches, and scientific practitioners with an interest in horizontal jumps.

Elite Athletes: The Necessity of Case-By-Case Analysis

The results presented in this paper emphasise the necessity of attending to how an athlete responds to physical and perceptual stimuli *before* initiating any technical intervention. Therefore, it is important to consider carefully how athletes execute skilful movements in their training and performance environment, particularly if an opportunity to enhance performance is being sought. An effective intervention for any athlete needs to recognise not only the individual differences demonstrated in the execution of gross motor skills but also, as stated by Newell et al. (2005), that “different types of information are differentially effective depending on the task to be learned and the skill level (dynamic state) of the learner” (p. 46). As such, detailed and individually focused analyses must be an essential precursor to any decision to initiate technical change.

Given that the type or source of information (cf. Savelsbergh & Van der Kamp, 2000) may differ depending on the individual preference of the athlete, the task itself and the skill level of the learner; with reference to the present cohort, and in view of the low levels of observed footfall variation in 4 of the 6 elite athletes in this study, there is the potential for consistent levels of foot-contacts between trials to be converted into a personalised auditory movement signature which could be utilised as a learning aid, or a pre-performance prime to cue prospective patterns of movement.

Supporting performance: Rhythmicity, Perception-Action or both?

Irrespective of the perceptual mechanisms through which an applied performance intervention operates, there are published, peer reviewed examples of individually tailored, temporally accurate, rhythmical, auditory representations of movement. One such example was developed by Collins, Morriss, and Trower (1999): The footfall of a javelin thrower was recorded and subsequently used to cue movement patterns and increase the resonance of mental imagery with the aim of facilitating performance following reconstructive surgery. Whilst *concurrent* auditory feedback is not a feasible proposition for the present cohort of athletes (the rules forbid it), using alternate sources of auditory information (Savelsbergh & Van der Kamp, 2000) to optimise movement appears to offer a viable solution to improving or maintaining performance in elite sport.

It is interesting to note that auditory cues, utilised in training and recalled in competitions, offer a number of potential advantages to the athlete: The sheer amount of information that can be carried in an auditory rhythm concerning the co-ordination of a movement pattern is considerable; furthermore, an auditory rhythm can indicate when the execution of a movement should commence, when it should cease and how a considerable number of the sub-routines involved in the whole movement could be organised in relation to one another (MacPherson et al., 2008; Agostini et al., 2003). Utilising an auditory cue is also in effect a pre-performance routine and a means of focusing processing capacity on the task rather than leaving space for attentional shift or anxiety to build. Recent evidence suggests that, even in the absence of sensory input, rhythmic movements can be produced by the central oscillators in the human brain to enable the assembly of ‘fictive’ motor patterns (Szirmai, 2010), the important implication being that complex movements rehearsed as rhythms do not need to be visually cued; therefore, the utility of a rhythmic intervention to an athlete is considerable because rhythmical footfall—which would necessarily have low levels of PFV—can act as a flexible learning aid designed to increase the vividness, controllability and temporal accuracy of an imagery intervention to mentally simulate prospective movement (Holmes & Collins, 2001). Although rhythmicity is not a performance panacea for all horizontal jumpers, the utility of an intervention grounded in motor control and supported by neuroscientific data (MacPherson et al., 2009) should at least be confirmed, or rejected, on an individual, case-by-case basis.

Whilst the use of visual or rhythmical auditory cues should be determined by performance data, there are pragmatic issues which merit consideration in the design of a performance-focused intervention in horizontal jumps. In the present case for example, while benefits may accrue for some athletes by pursuing a visual means of intervention, from an applied science perspective, there are a number of practical problems associated with its implementation and design. For example, after analysing one elite jumper's footfall who was not zeroing in on the take-off board it was suggested by Hay (1993) that, "In circumstances like these, visual feedback drills might become an important element in the training program of an athlete" (p. 1). What is being proposed by Hay (1993) is that athletes and their coaches should formulate a visual perception training program to improve accuracy on to the take-off board. This proposal would most likely involve using chevrons on the side of the runway to indicate proximity to the take-off board. Firstly, it is unlikely that provision for a training aid such as this would be permitted in international athletic competition; secondly, the elite athletes in question execute few maximum effort jumps in training. Thirdly, the uniformity of approach patterns has been shown to differ across sports: In an aforementioned study comparing the approach run of cricketers and long jumpers (Renshaw & Davids, 2006), the reason given for the lower variation footfall of cricketers is that bowlers do not need to reach peak horizontal velocity, and can decrease the amount of perceptual error in the run-up and distribute the accrued perceptual error throughout the entirety of the approach phase. In the present study, regarding the relatively stable footfall patterns demonstrated, the majority of the athletes analysed seem to have more in common with cricket bowlers than the horizontal jumpers examined in other approach studies. Notably, however, the athletes in this study were *also* focused on attaining maximum horizontal velocity; a clear contrast with the cricketers. As such, the reasons underlying this unexpected commonality are open to question; however, the mode of intervention—if required—lends itself toward rhythm, possibly to engender, augment and enhance perception-action coupling or merely to provide a more centrally led, power focused strategy.

In terms of capturing an auditory representation of an athlete's movement pattern, there are at least two means through which rhythms could be isolated: Firstly, each foot contact with the runway and contact with the take-off board could be digitised and an auditory signal assigned to each contact point. Secondly, a more straightforward approach could use a microphone attached near to one or both feet of the athlete and transmit or record the auditory signature that the footfall creates on approach to, and in contact with the take-off board.

To summarise, given the data we have collected and analysed; the examples of other successful rhythmical interventions discussed throughout this paper; an appreciation of the rules governing the sport in question, and how this relates to the feasibility of any proposed intervention; and an extensive review of pertinent empirical literature this has enabled us to formulate a clear case for the application of a rhythmic source of information to aid perceptual guidance in the athletes with low PFV. However, whether rhythm operates as the primary source of performance enhancement, or as Vroomen and de Gelder (2000) suggest, that vision and auditory cues (rhythm) enable the two perceptual systems to work in tandem to improve accuracy towards a target, remains to be determined.

Conclusions

This study has demonstrated that there are potentially serious consequences for athletes if practitioners uncritically adopt theoretical tenets associated with data collected with a primary focus on psychological research rather than perspectives yielded by bespoke, performance-focused investigation. In support of this contention, the majority of elite athletes in the present study jumped farther when they executed a low pattern of footfall variation on approach to the take-off board. Intriguingly, this *may* be associated with perception-action coupling, and therefore complement research carried out by Montagne et al. (2000) and Renshaw and Davids (2006; 2004). Whilst, further investigation is required before researchers can identify whether rhythmicity engenders perception-action coupling, or vice-versa, a research project could be designed to determine the effect of utilising a rhythmical auditory pattern as an alternative source of perceptual guidance (Savelsbergh & Van der Kamp, 2000) and, in so doing, create, improve or enhance perception-action coupling in events of this type and amongst cohorts of athletes with high ability. As such, our data provide an example of where competing but, perhaps complementary, explanations seem to offer a harmonious and effective solution.

Based on these findings, the use of rhythmical cues could be a useful prime for mental rehearsal in training and during warm-up for competition, *once each individual's preferred patterns have been established*. However, promotion of lowered PFV in training is problematic since athletes rarely jump at maximum effort from a full speed approach; as such, transfer for sub-optimum training jumps to full power competition performance may be limited. Crucially, further research is required to determine causation of PFV to distance travelled and to determine the extent to which training simulations at sub-optimum speed/rhythm are beneficial, or, indeed, detrimental to performance. In closing, we return to our most important message for scientist-practitioners….check before you apply!

References

Agostini, T., Righi, G., Galmonte, A., & Bruno, P. (2003). The relevance of auditory information in optimising hammer throwers performance. In P. Pascolo (Ed.), *XI Winter Universiads Proceedings Biomechanics and Sports* (pp. 67-74). New York: Springer Wien.

Baudry, L., Leroy, D., Thouvarecq, R., & Chollet, D. (2006). Auditory concurrent feedback benefits on the circle performed in gymnastics. *Journal of Sports Sciences*, *24*, 149 – 156.

Beavan, C. M., Gill, N. D., & Cook, C. J. (2008a). Salivary testosterone and cortisol responses in professional rugby players after four resistance exercise protocols. *Journal of Strength & Conditioning Research*, *22*, 426-431.

Beavan, C. M., Gill, N. D., & Cook, C. J. (2008b). Significant strength gains observed in rugby players after specific resistance exercise protocols based on individual salivary testosterone responses. *Journal of Strength & Conditioning Research*, *22*, 419-425.

Beek, P. J., Jacobs, D. M., Daffertshofer, A., & Huys, R. (2003). Views from the joint perspectives of ecological psychology and dynamical systems theory. In J. L. Starkes, & K.A. Ericsson (Eds.), *Expert Performance in Sports: Advances in Research in Expertise* (pp. 321-345). Champaign, IL: Human Kinetics.

Bellamy, M., Collins, D., Holmes, P., & Loze, G. M. (1999). Shot patterns in ECG recordings for elite air-pistol shooters. *Journal of Sport Sciences*, *17*, 48-49.

Buekers, M. (2000). Can we be so specific to claim that specificity is the solution for learning sport skills? *International Journal of Sports Psychology*, *31*, 485-489.

Chow, J. Y., Davids, K., Button, C., &., & Koh, M. (2006). Organisation of motor system degrees of freedom during the soccer chip: An analysis of skilled performance. *International Journal of Sport Psychology*, *37*, 207-229.

Clarke-Carter, D. (2001). *Doing Quantitative Psychological Research: From Design to Report*. Brighton, UK: Taylor & Francis.

Collins, D. J., Morriss, C., & Trower, J. (1999). Getting it back: A case study of skill recovery in an elite athlete. *The Sport Psychologist*, *13*, 288-299.

Cotterill, S. T., Sanders, R., & Collins, D. (2010). Developing effective pre-performance routines in golf: Why don't we ask the golfer? *Journal of Applied Sport Psychology*, *22*, 51-64.

Gibson, E. J., & Pick, A. D. (2000). *An Ecological Approach to Perceptual Learning and Development*. Oxford: Oxford University Press.

Hay, J. G. (1993). Citius, altius, longius (faster, higher, longer): The biomechanics of jumping for distance. *Journal of Biomechanics*, *26*, 7-21.

Hay, J. G., Miller, J. A., & Canterna, R. W. (1986). The technique of elite male long jumpers. *Journal of Biomechanics*, *19*, 855-866.

Helin, P., Sihvonen, T., & Hanninen, O. (1987). Timing of the triggering action in shooting in relation to the cardiac cycle. *British Journal of Sports Medicine*, *21* (1), 33-36.

Holmes, P. S., & Collins, D. J. (2001). The pettlep approach to motor imagery: A functional equivalence model for sport psychologists. *Journal of Applied Sport Psychology*, *13*, 60-83.

Hopkins, W. G. (2001). http://sportsci.org/resource/stats/ last accessed 13/6/2011

Landers, D. M., Christina, R. W., Hatfield, B. D., Daniels, G. S., & Doyle, L. A. (1980). Moving competitive shooting into the scientist's lab. *American Rifleman*, *128* (4), 36-37, 76-77.

Kline, P. (1993). *The Handbook of Psychological Testing*. London: Routledge.

Lee, D. N., Lishman, J. R., & Thomson, J. A. (1982). Regulation of gait in long jumping. *Journal of Experimental Psychology: Human Perception and Performance, 8,* 448-459.

Linthorne, N.P. (2007). Biomechanics of the long jump. In *Routledge Handbook of Biomechanics and Human Movement Science*, Y. Hong and R. Bartlett (Editors), Routledge, London. pp. 340–353.

MacPherson, A. C., Turner, A. P., & Collins, D. (2007). An investigation of natural cadence between cyclists and noncyclists. *Research Quarterly for Exercise and Sport, 78,* 396-400.

MacPherson, A. C., Collins, D., & Morriss, C. (2008). Is what you think what you get? Optimizing mental focus for technical performance. *The Sport Psychologist*, *22*, 288-303.

MacPherson. A. C., Collins, D., & Obhi, S. (2009). The importance of temporal structure and rhythm for the optimum performance of motor skills: A new focus for practitioners of sport psychology. *Journal of Applied Sport Psychology*, *21*, S49-61.

Montagne, G., Cornus, S., Glize, D., Quaine, F., & Laurent, M. (2000). A perception-action coupling type of control in long jump. *Journal of Motor Behavior, 32,* 37-43.

Moore, A. (personal communication, May 5, 2006).

Newell, K. M., Liu, Y. T., & Mayer-Kress, G. (2005). Learning in the brain-computer interface: Insights about degrees of freedom and degeneracy from a landscape model of motor learning. *Cognitive Process*, *6*, 37-47.

Renshaw, I., & Davids, K. (2004). Nested task constraints shape continuous perception-action coupling control during human locomotor pointing. *Neuroscience Letters*, *369,* 93-98.

Renshaw, I., & Davids, K. (2006). A comparison of locomotor pointing strategies in cricket bowling and long jumping. *International journal of Sport Psychology*, *37*, 1-20.

Savelsbergh, G. J. P., & Van der Kamp, J. (2000). Information in learning to co-ordinate and control movements: Is there a need for specificity of practice? *International Journal of Sports Psychology*, *31*, 467-484.

Schmidt, R. A., & Lee, T. D. (1999). *Motor control and learning a behavioral emphasis. Part 3 motor learning (3rd edition)*. Champaign, IL: Human Kinetics Publishers.

Singer, R. N. (2002). Pre- performance state, routines and automaticity: What does it take to realize expertise in self-paced events? *Journal of Sport & Exercise Psychology*, *24*, 359-375.

Szirmai, I. (2010). How does the brain create rhythms? *Ideggyogy Sz*, *63* (1-2), 13-23.

Vroomen, J., & de Gelder, B. (2000). Sound enhances visual perception: Cross-modal effects of auditory organisation on vision. *Journal of Experimental Psychology: Human Perception and Performance*, *26*, 1583-1590.

Warren, W. H. (1988). Action mode and laws of control for the visual guidance of action. In O.G. Meijer & K. Roth (Eds.), *Complex movement behavior: The motor-action controversy* (pp.339-380). Amsterdam: North-Holland.

Table 1. Subject Characteristics

	Sex of athlete	Number of competitions included in data set	Number of jumps in upper quartile (UQ)	Number of jumps in lower quartile (LQ)	Range of distances jumped in UQ	Range of distances jumped in LQ
Athlete 1	M	7	8	8	8 – 7.91	7.6-7.13
Athlete 2	F	8	3	2	6.67-6.51	6.13-5.6
Athlete 3	F	5	3	2	6.44-6.33	6.2-6.18
Athlete 4	M	5	4	4	8.02-7.94	7.64-7.54
Athlete 5	M	5	4	4	16.99-16.71	16.22-15.06
Athlete 6	M	7	4	4	17.47-17.1	16.67-16.21

Table 2. Upper versus lower quartile t-test results

Athlete	t-value	df	level of significance (2 tailed)	Effect size
1	- 4.156	14	**	1.1
2	- 4.559	14	**	1.3
3	1.33	14	n.s.	.74
4	9.377	14	***	.43
5	-8.801	14	***	1.9
6	1.014	14	n.s.	.24

***sig.001*
****sig.000*
n.s.– not significant

Figure 1

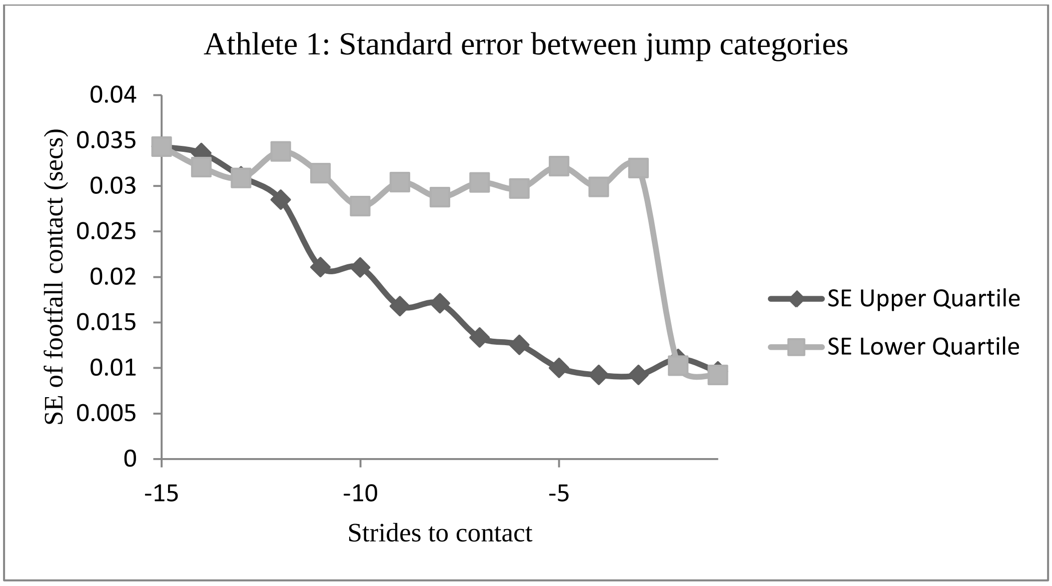


Figure 2

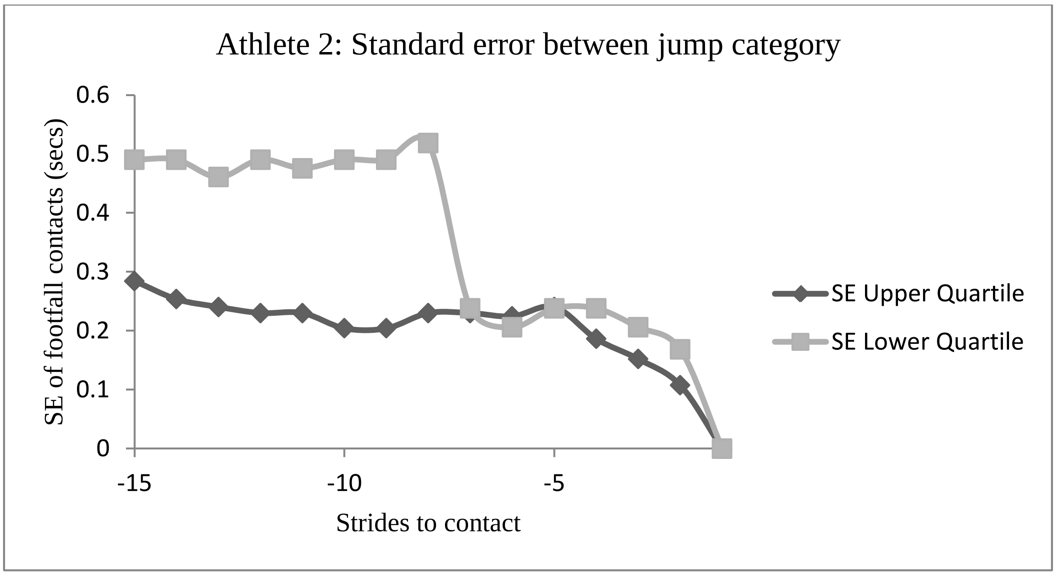


Figure 3

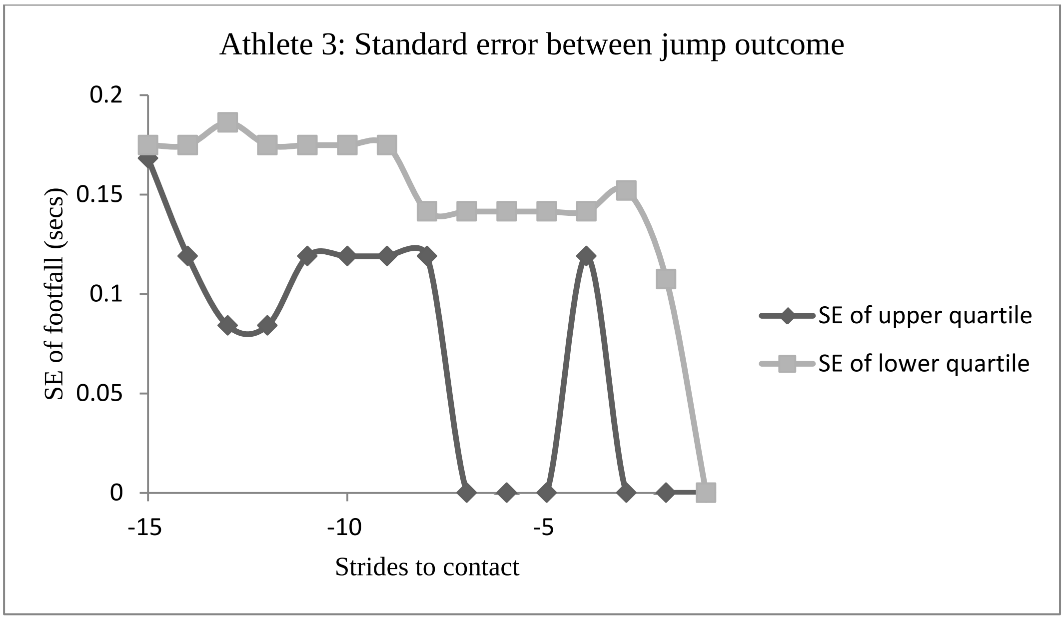


Figure 4

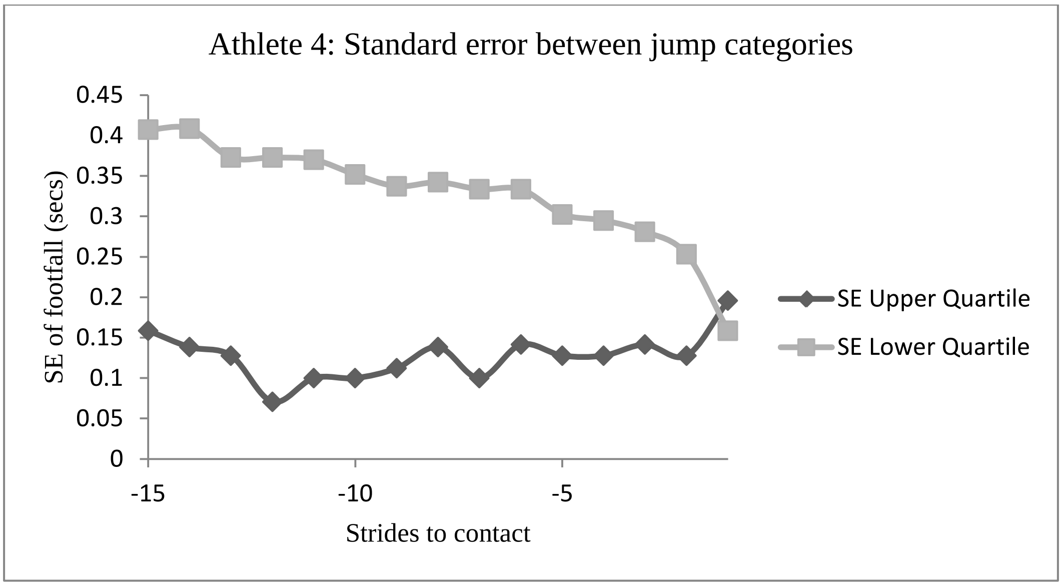
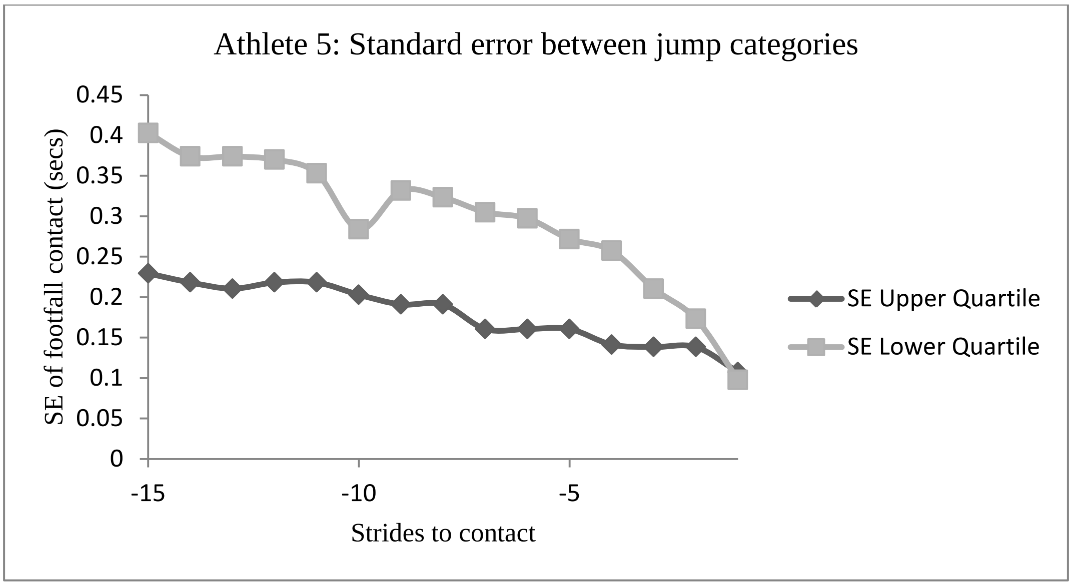
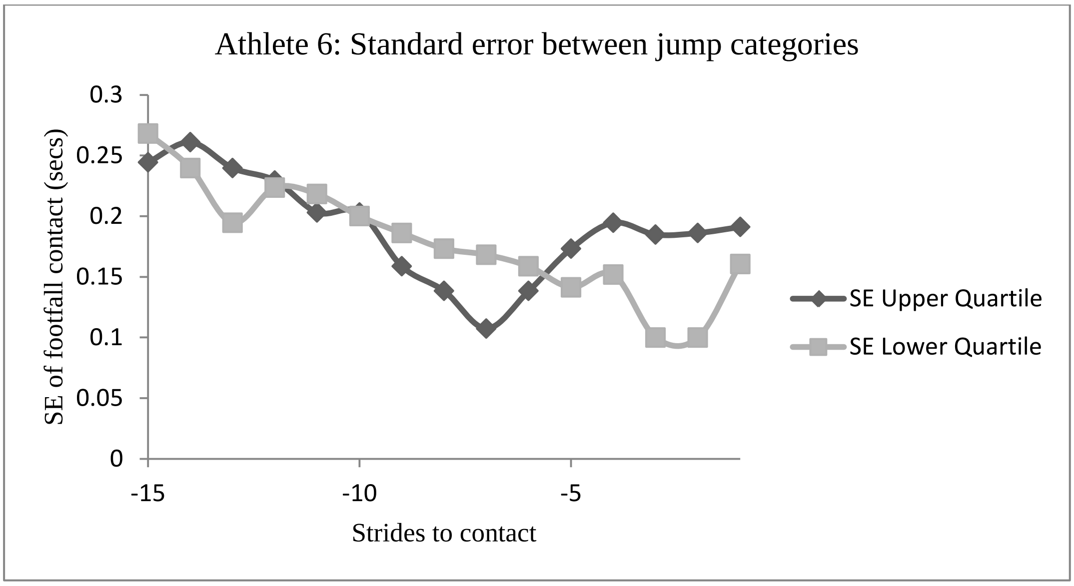


Figure 5



Athlete 6



Figures 1-6

(PFV) depicted the time taken to travel fifteen strides to the take-off board and how the intervening period is spent by the athlete. Athletes' pattern of footfall variation (PFV) was analysed by taking the standard error for each contact point; the timing of each foot contact was taken relative to the final contact with the take-off board. It was then possible to plot the variability for each athlete.