European Journal of Sport Science

ISSN: 1746-1391 (Print) 1536-7290 (Online) Journal homepage: http://www.tandfonline.com/loi/tejs20

Representative learning design in springboard diving: Is dry-land training representative of a pool dive?

Sian Barris, Keith Davids & Damian Farrow

To cite this article: Sian Barris, Keith Davids & Damian Farrow (2013) Representative learning design in springboard diving: Is dry-land training representative of a pool dive?, European Journal of Sport Science, 13:6, 638-645, DOI: 10.1080/17461391.2013.770923

To link to this article: http://dx.doi.org/10.1080/17461391.2013.770923

European Journal of Sport Science, 2013
Vol. 13, No. 6, 638–645, http://dx.doi.org/10.1080/17461391.2013.770923

Routledge
Taylor & Francis Group

ORIGINAL ARTICLE

Representative learning design in springboard diving: Is dry-land training representative of a pool dive?

SIAN BARRIS[1,2], KEITH DAVIDS[1], & DAMIAN FARROW[2,3]

[1]*School of Exercise and Nutrition Sciences, Queensland University of Technology, Brisbane, Australia,* [2]*Australian Institute of Sport, Leverrier Crescent, Canberra, Australia,* [3]*Institute of Sport, Exercise and Active Living, School of Sport and Exercise Science, Victoria University, Melbourne, Australia*

Abstract
Two distinctly separate training facilities (dry-land and aquatic) are routinely used in springboard diving and pose an interesting problem for learning, given the inherent differences in landing (head first vs. feet first) imposed by the different task constraints. Although divers may practise the same preparation phase, take-off and initial aerial rotation in both environments, there is no evidence to suggest that the tasks completed in the dry-land training environment are representative of those performed in the aquatic competition environment. The aim of this study was to compare the kinematics of the preparation phase of reverse dives routinely practised in each environment. Despite their high skill level, it was predicted that individual analyses of elite springboard divers would reveal differences in the joint coordination and board-work between take-offs. The two-dimensional kinematic characteristics were recorded during normal training sessions and used for intra-individual analysis. Kinematic characteristics of the preparatory take-off phase revealed differences in board-work (step lengths, jump height, board depression angles) for all participants at key events. However, the presence of scaled global topological characteristics suggested that all participants adopted similar joint coordination patterns in both environments. These findings suggest that the task constraints of wet and dry training environments are not similar, and highlight the need for coaches to consider representative learning designs in high performance diving programmes.

Keywords: *Springboard diving, practice, representative learning design, practice task constraints, task decomposition*

1. Introduction

Ecological approaches to understanding motor performance have identified the importance of examining the physical and social environments in which activity occurs (Araújo & Davids, 2009; Araújo, Davids, & Hristovski, 2006; Araújo, Davids, & Passos, 2007; Davids, Button, & Bennett, 2008). *Representative design*, a concept introduced in psychology by Brunswik (1956), refers to the composition of experimental task constraints so that they *represent* the behavioural setting to which the results of an investigation are intended to be generalised (for detailed discussion see Dhami, Hertwig, & Hoffrage, 2004; Pinder, Davids, Renshaw, & Araújo, 2011b). Araújo et al. (2007) contended that, without representative design, an experimental environment becomes a stand-alone environment, not representative of the performance environments to which the results might be generalised. Instead, it was proposed that scientists should understand how to represent those messy, irregular conditions in the design of empirical research and practice to discover how individuals overcome uncertainty in adapting to their natural performance environments (Araújo et al., 2007; Brunswik, 1956). These valuable ideas highlight an important issue for applied sports science research and support, where there is potential for the resultant behaviours of an individual required to perform a task in a controlled laboratory or practice/training environment, to be influenced by this prior knowledge and associated expectations (Araújo et al., 2007).

Correspondence: S. Barris, School of Exercise and Nutrition Sciences, Queensland University of Technology, Victoria Park Road, Kelvin Grove, Brisbane 4059, Australia. E-mail: sian.barris@gmail.com

More recently, some ecological psychologists interested in learning and performance in sport have adapted Brunswik's original concept to study how task constraints in learning or practice environments can faithfully simulate the constraints encountered in a competitive performance context (Araújo et al., 2007; Davids, Araújo, Button, & Renshaw, 2007; Davids, Glazier, Araújo, & Bartlett, 2003; Dicks, Davids, & Araújo, 2008). Based on this work, the idea of *representative learning design* refers to ensuring that the task constraints employed in training environments *where learning may occur* (e.g. during practice) are representative of those encountered by athletes in a competitive performance context. These arguments suggest that representative design is also important in the context of practice and performance analysis in sport, where small changes in task constraints can lead to substantial changes in movement behaviours used to achieve specific performance goals (Hristovski, Davids, Araújo, & Button, 2006; Jobson et al., 2007; Wilson, Simpson, van Emmerick, & Hamill, 2008). Consequently, the design of sports science research and practice tasks need to allow athletes to perform (and learn) the same movement responses as those which are functional in competitive performance environments (Pinder, Davids, Renshaw, & Araújo, 2011a; Pinder, Renshaw, & Davids, 2009; Renshaw & Fairweather, 2000).

The degree of association between behaviour in an experimental task with that of the performance setting to which it is intended to generalise, is known as action fidelity (Araújo et al., 2007; Lintern, Sheppard, Parker, Yates, & Nolan, 1989). The purpose of action fidelity is to examine whether a performer's responses (e.g. actions or decisions) remain similar in two or more contexts (e.g. a flight simulator compared to flying a plane; Pinder et al., 2009; Stoffregen, Bardy, Smart, & Pagulayan, 2003). In this respect, practice, training and learning tasks in diving could also be viewed as simulations of the performance environment that need to be high in action fidelity. If the emergent actions are highly dissimilar, it is likely that differences in task constraints between simulations (training) and simulated (competitive) environments might indicate low levels of action fidelity with potential implications for athlete development (see Araújo et al., 2006). In this study, the degree of fidelity was assessed by measuring practice performance of elite athletes (e.g. board-work, joint kinematics) in both a simulated (dry-land) training environment and an aquatic competitive performance context (Araújo et al., 2007). Consequently, important questions exist regarding the extent to which behaviours in one context (dry-land practice) correspond to those in another context (aquatic environment), as believed by the athletes and coaches (Araújo et al., 2007).

Biomechanical analyses of the dive take-off have shown that the preparatory movements in diving (approach and hurdle phases) are the precursors that facilitate the actual execution of dives (Miller, 1984; Slobounov, Yukelson, & O'Brien, 1997). These studies have revealed that preparation for aerial phase of the dive is most predictive of performance success in diving. In this work, efficient execution of these initial movements was observed to be vital for the overall achievement of the performance goal (a good approach and hurdle typically led to a good body position, good height off the board, good rotation and good entry into the water) (See Figure 1).

Elite divers currently train between 28 and 30 hours per week and use both aquatic and dry-land training environments. In the pool they complete seven or eight repetitions of each dive with functional 'wrist first' entries into the water before moving on to the next skill. In contrast, the dry-land training environment is in a purpose-built gymnasium designed for land-based diving practice (see Figure 1 for examples of equipment and activities). The focus of this research is on those skills performed on the dry-boards, see Figure 2(b). Dry-boards are springboards set-up over large foam mats that allow divers to practise the early preparatory phase of the dive take-off with a feet-first landing. The coaching strategy behind the use of this training facility is that allows divers to experience a higher volume of dives during practice than they can achieve in the pool environment where time is lost exiting the water and climbing towers to the springboard (personal communication with the National Head Coach, August 2009). The motor-learning strategy behind the use of a dry-land training environment is based on the assumed value of allowing athletes (directed by their coaches) to isolate small components of a dive coordination pattern and practise them independently. This motor-learning approach has been termed *task decomposition* (Davids, Kingsbury, Bennett, & Handford, 2001). For example, the approach phase (initial steps, hurdle step, hurdle jump) and take-off can be isolated and practised on dry-land springboards. However, the constraints of the practice environment prevent the same number of somersaults being performed in the dry-land as in pool area practice or elite competition. Furthermore, athletes are required to perform variable landings in both areas. For example, in the dry-land area, a diver can complete one or two somersaults before landing feet first on the mat or in the foam pit.

The use of these two distinctly separate training facilities in the elite diving training programme poses an interesting problem for motor learning, given the inherent differences in landing (head first vs. feet first) and the information sources imposed by the different practice task constraints. Although divers

Figure 1. An example of the approach (a and b) and hurdle (c–e) phases of a reverse dive take-off.

may practise the *same* preparation phase, take-off and initial aerial rotation in both environments, to date, there is actually no evidence to suggest that the task components completed in the dry-land training environment are representative of those performed in the aquatic competition environment. Although the rationale for dry-land training is to allow the athlete to isolate small manageable parts of the task, the constraints placed on the training tasks in the dry-land facility (fewer somersaults and a feet-first landing), may compel athletes to create novel movement patterns that are neither functional for, nor representative of, performance in competitive environments. In order to investigate this critical issue, the aim of this study was to compare the kinematics of the preparation and take-off phases of two reverse dives routinely practised in each training environment: the reverse two and half somersault in the pool (3 m) and the reverse somersault (with feet-first landing) in the dry-land. Despite their high skill level, it was predicted that individual analyses of elite springboard divers' performance would reveal differences in joint coordination (i.e. kinematic differences evidenced by changes in coordination pattern size and shape), and board-work (e.g. divers' movements on the springboard, step lengths and jump heights) between take-offs completed feet first in the dry-land and those performed wrist first in the pool (3 m). These differences were expected as a consequence of the distinct task constraints of the two training environments, and the decomposition of the task.

2. Method

Six elite springboard divers (five female, one male, mean age: 18.3 ± 2.33, height: 161.6 cm ± 3.56, weight: 63 kg ± 5.9 and years of experience: 8 ± 2.5) who were all National representatives, free from injury and currently in training were recruited for this study and provided written informed consent. The experimental protocols received approval from two local research ethics committees.

Flat 14 mm tape was fixed to 12 lower body limb landmarks on both the right and left sides of the body (anterior superior iliac spine, thigh, knee, shank, ankle, toe), ensuring an optimal position for minimising visual occlusion (Slobounov et al., 1997). Additional markers were placed on the side of the springboard (at 0.5, 1, 1.5 and 2 m from the oscillating end) in direct line with the camera for calibration of the filming environment and to assist with step and hurdle length measurements.

Divers participated in two testing sessions: in the dry-land training facility and in the aquatic complex. Divers performed the same springboard dive *take-off phases* (approach and hurdle steps, see Figure 2) of the reverse take-off, where the diver faces forward and rotates backward towards the springboard, in each environment. However, in the dry-land condition divers only completed a partial dive (one somersault) and landed feet first on a foam mat, as they would normally do in practice to simulate components of a reverse 2½ somersault dive in the pool. In the pool-based protocol, divers completed traditional wrist first entries from a 3 m springboard. No additional or specific instructions, corrections or comments were provided to the athletes by the researchers during data collection.

The preparation phase of five randomly selected reverse take-offs were captured for each participant in each environment using one stationary camera (Sony HDV-FX1 HDV 1080i, 60 Hz) positioned

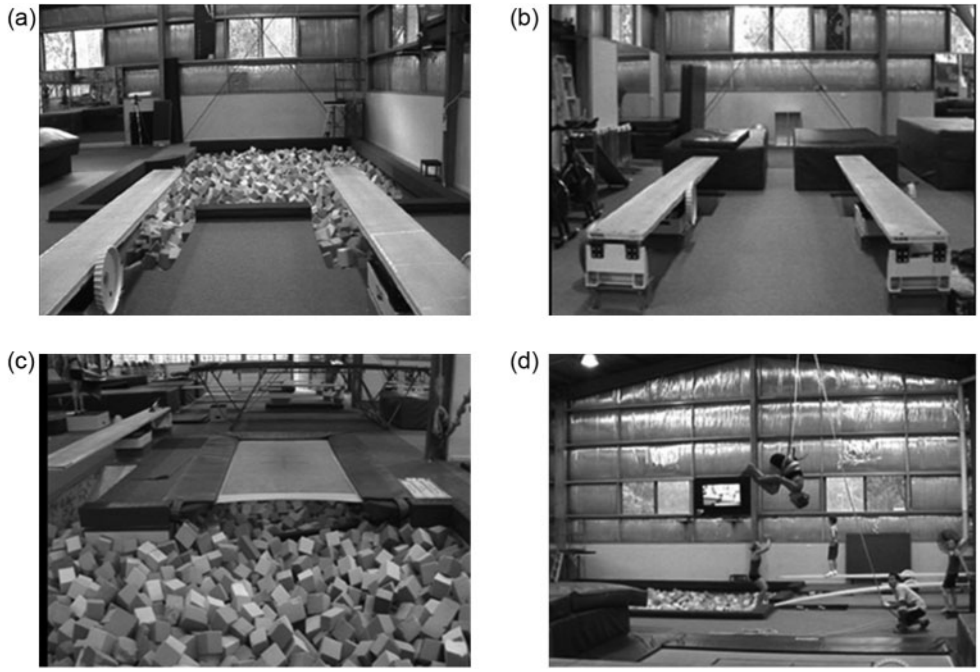

Figure 2. Dry-boards and trampolines in the Australian Institute of Sport (AIS) dry-land training facility.

perpendicular to the side of the diving board in the sagittal plane (approximately 90°) and at heights of 1.5 and 4.5 m in the dry-land and aquatic facilities, respectively (Slobounov et al., 1997). A sufficient focal length was chosen that permitted the recording of the whole dive movement and allowed the digitisation of the relevant body markers (Barris, Farrow, & Davids, 2012; Slobounov et al., 1997). The two-dimensional kinematic analyses of each take-off were achieved by manual digitisation of the key anatomical landmarks using PEAK Motus™ Motion Analysis Software (Oxford, UK). The data were filtered using a second order low-pass Butterworth digital filter with a cut-off frequency of 6 Hz (Miller & Munro, 1984).

Data were separated and analysed in two phases: board-work and joint kinematics. The first phase examined the divers' movements on the springboard. This analysis included: step lengths during the forward approach (two normal walking steps); the length of the hurdle step (long lunge like step); and the hurdle jump distance (two foot take-off – one foot landing). All step and jump lengths were measured as the distance in centimetres between heel-strike and toe-off. Additionally, hurdle jump height (distance (cm) between the tip of the springboard and toes), flight time (s) during hurdle jump and the maximum angle (°) of springboard depression during the hurdle jump landing were all recorded.

The second phase analysed the participants' joint kinematics at the same key events (e.g. approach step, hurdle jump, flight time and maximum board depression angle) during dives completed in the dry-land and aquatic environments. Angle–angle diagrams were used to qualitatively assess the topological equivalence of the two tasks (Bartlett, 2007). Shapes are considered to be topologically equivalent if one can just be 'stretched' to form the other. The topological characteristics of a movement describe the motions of the body segments relative to each other and changes in these patterns can provide evidence that specific aspects of coordination have changed (Anderson & Sidaway, 1994; Chow, Davids, Button, & Koh, 2008).

3. Results

An intra-individual analysis examined differences in divers' movement patterns during take-offs completed in the dry-land and the pool with feet first and traditional entries, respectively. Descriptive statistics revealed differences between dry-land and aquatic take-offs for all participants at various key performance milestones (for details see Table I). The most noticeable differences in dive take-off between environments began during the hurdle (step, jump and height) where the diver generates the necessary momentum to complete the dive. Consequently, greater step lengths and jump heights resulted in greater board depression prior to take-off in the aquatic environment where the dives required greater amounts of rotation.

Wilcoxon signed-rank tests showed significant differences ($p < 0.05$) at key events (approach step 2, hurdle step, hurdle jump distance and height,

Table I. Means and standard errors at key events during the preparation and approach phases of dive take-offs in the dry-land and aquatic training facilities

P		Approach step 1 (cm)	Approach step 2 (cm)*	Hurdle step (cm)*	Hurdle jump distance (cm)*	Jump height (cm)*	Hurdle jump flight (s)*	Board angle hurdle (°)*	Board angle landing (°)*
1	Mean dry	49.2 (1.30)	46.2 (2.58)	9.6 (1.94)	96.2 (4.32)	81.2 (3.56)	0.86 (0.02)	10.64 (0.05)	13.84 (0.01)
	Mean pool	49.0 (2.0)	49.8 (1.30)	11.0 (1.0)	106 (2.0)	93.4 (1.14)	0.88 (0.01)	12.76 (0.18)	15.8 (0.21)
2	Mean dry	63.2 (2.05)	54.8 (2.59)	146 (3.24)	**	83.6 (4.28)	0.912 (0.02)	10.94 (0.04)	15.7 (0.04)
	Mean pool	62 (2.0)	57.6 (2.51)	157.2 (1.48)	**	102.8 (2.95)	1.01 (0.02)	15.68 (0.18)	19.06 (0.15)
3	Mean dry	43.2 (2.28)	48.2 (2.77)	9.8 (1.48)	88.0 (3.46)	54.3 (3.60)	0.592 (0.01)	9.82 (0.71)	13.3 (0.03)
	Mean pool	41.4 (1.52)	52.8 (2.17)	10.6 (0.89)	94.2 (1.64)	62.6 (1.14)	0.728 (0.02)	11.68 (0.13)	14.8 (0.2)
4	Mean dry	39.4 (2.07)	57 (1.58)	10.4 (1.14)	97.4 (2.07)	83.2 (1.92)	0.874 (0.01)	12.64 (0.05)	14.42 (0.24)
	Mean pool	40.1 (1.52)	63.6 (0.02)	11.2 (0.02)	103.9 (0.04)	93.8 (0.07)	0.942 (0.08)	13.32 (0.30)	15.48 (0.35)
5	Mean dry	21.0 (3.74)	32.8 (1.30)	20.2 (3.56)	89.0 (1.58)	73.4 (5.03)	0.804 (0.02)	11.4 (0.55)	15.2 (.055)
	Mean pool	26.6 (1.52)	36.6 (1.51)	33.6 (0.07)	94.0 (1.0)	81.4 (1.51)	0.894 (0.02)	13.26 (0.23)	15.34 (0.27)
6	Mean dry	46.2 (1.64)	44.0 (1.22)	9.2 (1.64)	63.0 (2.78)	47.4 (4.56)	0.622 (0.02)	9.8 (0.29)	13.2 (0.21)
	Mean pool	50 (1.41)	48.6 (1.82)	11.4 (1.34)	70.3 (1.18)	56.0 (1.58)	0.732 (0.01)	12.24 (0.15)	15.5 (0.4)

*Significant differences present between dry-land and pool.
**Diver does not do a small hurdle step and jump, instead performing one long hurdle lunge.

flight time and board angles during the hurdle and at landing) during the preparation phase of dive take-offs completed in dry-land and aquatic training environments (see Table I). For example, participants displayed significantly smaller step lengths in the second approach step during take-offs completed in the dry-land area ($M = 47.1$ (8.64), than those completed in the pool area ($M = 51.5$ (9.15), $z = -2.207$, $p < 0.05$). Similarly, participants showed significantly smaller hurdle jump height values during take-offs completed in the dry-land area ($M = 70.5$ (15.8), than those completed in the pool area ($M = 81.6$ (18.7), $z = -2.201$, $p < 0.05$). Further, participants showed significantly less board angle depression at landing (from the hurdle jump) during take-offs completed in the dry-land area ($M = 14.27$ (1.02), than those completed in the pool area ($M = 15.99$ (1.53), $z = -2.201$, $p < 0.05$). There were no significant differences between conditions in the first approach step.

Ankle – shank and shank–thigh angle–angle plots were constructed for both lower limbs to qualitatively depict any differences in intra-limb coordination between take-offs completed in the dry-land and those performed in the aquatic environment. Overall, qualitative angle–angle diagrams demonstrated similarities in joint coordination patterns between training environments for all participants (see Figure 3). However, large differences were observed in the scaling of the movement patterns between conditions at some joints throughout the movement. While data displayed in Figure 3 are for Participants One and Six, these findings were representative across all individuals in the study, where all divers demonstrated similar scaling of the movement patterns (e.g. smaller range of motion) during the dry-land task and greater range of motion during performance of the aquatic tasks.

4. Discussion

This study investigated whether observable differences existed between the movement kinematics of elite divers in the preparation phases of dives completed in the dry-land and aquatic environments. Despite their high skill level, it was expected that differences would be observed in the movement patterns (i.e. kinematic differences evidenced by changes in coordination pattern size and shape) and board-work (e.g. divers' movements on the springboard, step lengths and jump heights) between take-offs completed feet first in the dry-land and those performed wrist first in the pool (3 m).

Individual analyses revealed topological similarities in the shapes of the coordination plots between conditions for all participants. However, large differences were observed between conditions (evidenced

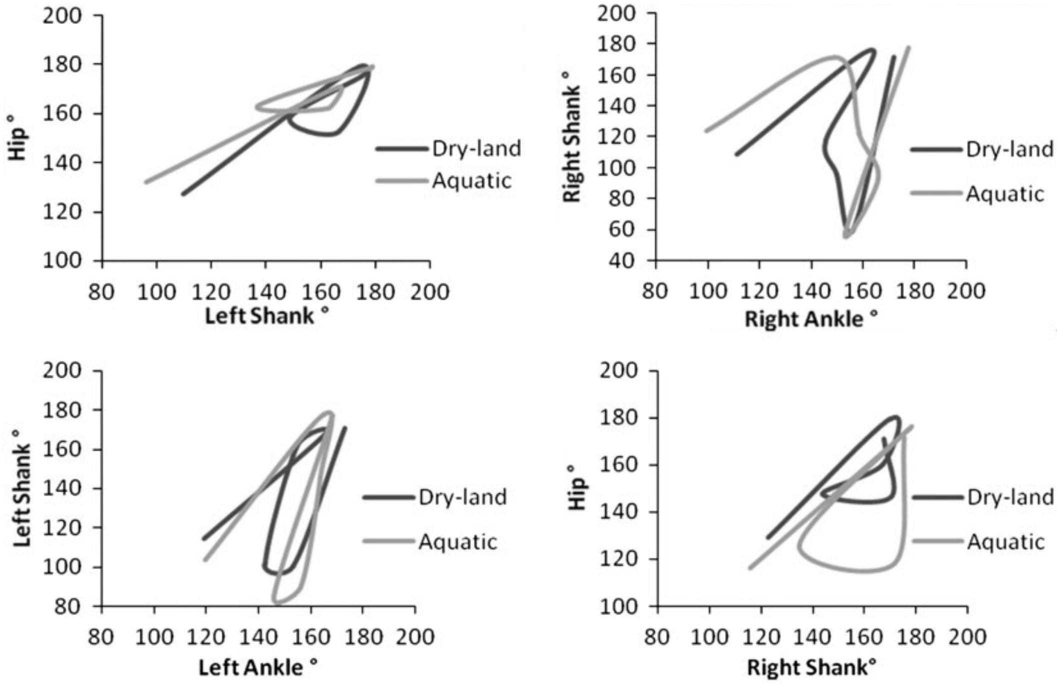

Figure 3. Examples of mean angle–angle plots for dives completed in the dry-land and aquatic environments for Participants One (top) and Six (bottom).

by greater ranges of motion in the pool dives) at some joints at key events throughout the movement. This observation suggests that, although the movement patterns are not different between conditions, functional differences may exist at specific joints during coordination that determine whether the divers can create enough height and momentum to complete the necessary somersaults. These findings are further supported by data recorded at the key events (e.g. step lengths, jump height) during the approach and hurdle phases of the take-off, where participants showed significantly greater step lengths, jump heights and board depression angles (during the hurdle jump and at landing prior to take-off) in the aquatic environment compared to the dry-land.

These findings are in line with data reported by Pinder and colleagues (2009) who analysed the movements of cricket batters when responding to ball deliveries from a 'live' bowler and a ball projection machine. In this situation, a ball machine was used to simulate the bowler in the performance environment. Similarly, the differences observed between the movement patterns of reverse dive take-offs completed in the dry-land and aquatic training environments in this study are arguably the consequence of changes in task constraints, which are imposed by differences in the two training environments. Specifically, the height of the springboard, the foam landing mats and the limited number of somersaults that can be completed in the dry-land, results in the decomposition of the dive take-off task and changes the overall task execution (feet first vs. wrist first landing).

The conditions of practice are a fundamental issue for the acquisition of skill and optimisation of performance in sport, and questions have regularly be asked regarding whether a learner should practise the whole task from the beginning or whether the task should be decomposed into parts that are practised separately (Newell, Carlton, Fisher, & Rutter, 1989). Intentionally or not, the process of task decomposition is common in diving practice where the environmental constraints force the diver to modify the skill to land feet first rather than wrist/head first as in the aquatic environment. Task decomposition techniques in sports training, which have dominated traditional pedagogical approaches, aim to make informational loads more manageable, reduce the attentional demands on the performer during skill acquisition and positively transfer learning of the component (e.g. a reverse dive take-off) to performance of the whole task (e.g. a reverse 2½ somersault dive; Araújo, Davids, Bennett, Button, & Chapman, 2004; Davids et al., 2001; Naylor & Briggs, 1963). However, this pedagogical method also tends to rupture the link between information and movement, breaking up potential information–movement couplings which are used to regulate behaviours (Araújo et al., 2004; Montagne, Cornus, Glize, Quaine, & Laurent, 2000). Consequently, valuable information regarding the dynamics of the movement may be lost if each of these segments are practised in isolation or removed from the competitive performance context, potentially changing the task constraints, as observed in the current investigation (Hamill, Haddad, & van Emmerick, 2005). In this instance, the context becomes a stand-alone environment and not representative of the performance context to which the practice results are generalised (Araújo et al., 2007).

Previous research has demonstrated how the nature of the task can greatly influence the value of the learning strategy (Frederiksen & White, 1989; Naylor & Briggs, 1963). In particular, tasks that have highly interdependent parts or complex coordination requirements, like diving or gymnastics, may not benefit from part-task or decomposition practice (Frederiksen & White, 1989; Naylor & Briggs, 1963). Instead, it has been suggested that practising a simplified version of the whole task is more effective for complex skills, than practising separate components, and then applying to them to a whole task at the end of training (Davids et al., 2001; Dicks et al., 2008; Gopher, Weil, & Seigel, 1989; Schneider, 1985; Wrightman & Lintern, 1985). The task simplification approach maintains the coherence of the task and the perception–action cycles remain intact during practice. This pedagogical approach ensures that key perceptual variables remain available to the performer to pick up and continuously use to support action (Dicks et al., 2008). To exemplify, a coach might gently feed a ball to a tennis player early in learning, rather than designing a practice task for the learner to hit a ball projected from a ball machine. Similarly, in diving, task simplification may be exemplified by the completion of full dives (rather than separate take-off and entry drills or landing feet first), which can only be achieved in the pool, with take-off, rotation and entries intact, but manipulating the number of rotations in the air, and gradually increasing the dive complexity.

5. Conclusion

It has been argued that a *representative learning design*; the composition of practice task constraints so that they *represent* the performance setting, is crucial for the acquisition of skilled behaviours. Biomechanical analyses of the dive take-off have shown that the preparatory movements in diving (particularly the approach and hurdle phases) are the precursors that facilitate the actual execution of dives (Miller, 1984; Slobounov et al., 1997). Consequently, divers routinely isolate components of the dive, practising the preparatory phase of the take-off in the dry-land training facility, in order to achieve an efficient, invariant take-off. However, the results of this investigation have highlighted the existence of key differences in the preparatory phases of reverse dive take-offs completed by elite springboard divers during performance of their typical training tasks in the dry-land and aquatic training environments. The data suggest that there may not be any performance advantages associated with practising the preparatory phase of the dive take-off in isolation as traditionally assumed. In this instance, task simplification may be a more beneficial approach to learning, rather than decomposition.

Finally, although the findings of this study displayed differences in the preparatory phase of the dive take-off in the dry-land and aquatic environments due to task decomposition, it is important to note that only one aspect (the preparatory phase) of the decomposed task was analysed. The extent to which other dry-land practice tasks, such as the aerial phase (somersaulting on the trampoline), or ‘come out’ phase (transition from somersaulting position to final water entry position), may contribute to the successful transfer of isolated phases into the whole task remains unknown and should be subject to further research.

Acknowledgements

The first author was supported by a Postgraduate Scholarship from the Australian Sports Commission, Diving Australia and Queensland University of Technology. The authors have no conflicts of interest to declare that are directly relevant to the content of this article. No funding was received by the other authors to assist them in the preparation of this article. The authors would like to thank Diving Australia and the Australian Institute of Sport diving programme for their support with this study.

References

Anderson, D., & Sidaway, B. (1994). Coordination changes associated with practice of a soccer kick. *Research Quarterly for Exercise & Sport*, *65*(2), 93–99.

Araújo, D., & Davids, K. (2009). Ecological approaches to cognition and action in sport and exercise: Ask not only what you do, but where you do it. *International Journal of Psychology*, *40*(1), 5–37.

Araújo, D., Davids, K., Bennett, S., Button, C., & Chapman, G. (2004). Emergence of sport skills under constraints. In A. M. W. N. J. Hodges (Ed.), *Skill acquisition in sport: Research, theory and practice* (pp. 409–433). London: Routledge, Taylor & Francis.

Araújo, D., Davids, K., & Hristovski, R. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise*, *7*(6), 653–676. doi:10.1016/j.psychsport.2006.07.002

Araújo, D., Davids, K., & Passos, P. (2007). Ecological validity, representative design and correspondence between experimental task constraints and behavioural setting: Comment on Rogers, Kadar and Costall. *Ecological Psychology*, *19*(1), 69–78. doi:10.1080/10407410709336951

Barris, S., Farrow, D., & Davids, K. (2012). Do the kinematics of a baulked take-off in springboard diving differ from a completed dive? Journal of Sport Sciences. doi:10.1080/02640414.2012.733018

Bartlett, R. (2007). *Introduction to sports biomechanics*. London: Routledge.

Brunswik, E. (1956). *Perception and the representative design of psychological experiments*. Berkeley: University of California Press.

Chow, J., Davids, K., Button, C., & Koh, M. (2008). Coordination changes in a discrete multi-articular action as a function of practice. *Acta Psychologica*, *127*, 163–176. doi:10.1016/j.actpsy.2007.04.002

Davids, K., Araújo, D., Button, C., & Renshaw, I. (2007). Degenerate brains, indeterminate behavior and representative tasks: Implications for experimental design in sport psychology research. In G. T. R. Eklund (Ed.), *Handbook of sport psychology* (3rd ed., pp. 224–241). New York: Wiley.

Davids, K., Button, C., & Bennett, S. (2008). *Dynamics of skill acquisition: A constraints led approach*. Champaign, IL: Human Kinetics Publishers.

Davids, K., Glazier, P., Araújo, D., & Bartlett, R. (2003). Movement systems and dynamical systems: The functional role of variability and its implications for sports medicine. *Sports Medicine*, *33*(4), 245–260. doi:10.2165/00007256-200333040-00001

Davids, K., Kingsbury, D., Bennett, S., & Handford, D. (2001). Information-movement coupling: Implications for the organisation of research and practice during acquisition of self-paced extrinsic timing skills. *Journal of Sports Sciences*, *19*, 117–127. doi:10.1080/026404101300036316

Dhami, M., Hertwig, R., & Hoffrage, U. (2004). The role of representative design in an ecological approach to cognition. *Psychological Bulletin*, *130*(6), 959–988. doi:10.1037/0033-2909.130.6.959

Dicks, M., Davids, K., & Araújo, D. (2008). Ecological psychology and task representativeness: Implications for the design of perceptual-motor training programmes in sport. In Y. Hong & R. Bartlett (Eds.), *The Routledge handbook of biomechanics and human movement science* (pp. 129–140). London: Routledge.

Frederiksen, J., & White, B. (1989). An approach to training based upon principled task decomposition. *Acta Psychologica*, *71*, 89–146. doi:10.1016/0001-6918(89)90006-1

Gopher, D., Weil, M., & Seigel, D. (1989). Practice under changing priorities: An approach to training complex skills. *Acta Psychologica*, *71*, 147–177. doi:10.1016/0001-6918(89)90007-3

Hamill, J., Haddad, J., & van Emmerick, R. (2005, August). *Using coordination measures for movement analysis*. Paper presented at the XXIII International Symposium on Biomechanics in Sports, Beijing, China.

Hristovski, R., Davids, K., Araújo, D., & Button, C. (2006). How boxers decide to punch a target: Emergent behaviour in nonlinear dynamical movement systems. *Journal of Sport Science & Medicine*, *5*, 60–73.

Jobson, S. A., Nevill, A. M., Palmer, G. S., Jeukendrup, A. E., Doherty, M., & Atkinson, G. (2007). The ecological validity of laboratory cycling: Does body size explain the difference between laboratory- and field-based cycling performance? *Journal of Sports Sciences*, *25*(1), 3–9. doi:10.1080/02640410500520526

Lintern, G., Sheppard, D., Parker, D., Yates, K., & Nolan, M. (1989). Simulator design and instructional feature for air-to-ground attack: A transfer study. *Human Factors*, *31*, 87–99.

Miller, D. (1984). Biomechanical characteristics of the final approach step, hurdle and take-off of elite American springboard divers. *Journal of Human Movement Studies*, *10*, 189–212.

Miller, D., & Munro, C. (1984). Body segment contributions to height achieved during the flight of a springboard dive. *Medicine & Science in Sports & Exercise*, *16*(3), 234–242. doi:10.1249/00005768-198406000-00007

Montagne, G., Cornus, S., Glize, D., Quaine, F., & Laurent, M. (2000). A perception-action type of control in long jumping. *Journal of Motor Behavior*, *32*, 37–43. doi:10.1080/00222890009601358

Naylor, J., & Briggs, G. (1963). Effects of task complexity and task organization on the relative efficiency of part and whole training methods. *Journal of Experimental Psychology*, *65*, 217–224. doi:10.1037/h0041060

Newell, K., Carlton, M., Fisher, A., & Rutter, B. (1989). Whole-part training strategies for learning the response dynamics of microprocessor driven simulators. *Acta Psychologica*, *71*, 197–216. doi:10.1016/0001-6918(89)90009-7

Pinder, R., Davids, K., Renshaw, I., & Araújo, D. (2011a). Manipulating informational constraints shapes movement reorganization in interceptive actions. *Attention, Perception, & Psychophysics*, *73*(4), 1242–1254. doi:10.3758/s13414-011-0102-1

Pinder, R., Davids, K., Renshaw, I., & Araújo, D. (2011b). Representative learning design and functionality of research and practice in sport. *Journal of Sport & Exercise Psychology*, *33*, 146–155.

Pinder, R., Renshaw, I., & Davids, K. (2009). Information-movement coupling in developing cricketer under changing ecological practice constraints. *Human Movement Science*, *28*, 468–479. doi:10.1016/j.humov.2009.02.003

Renshaw, I., & Fairweather, M. (2000). Cricket bowling deliveries and the discrimination ability of professional and amateur batters. *Journal of Sports Sciences*, *18*(12), 951–957. doi:10.1080/026404100446757

Schneider, W. (1985). Training high performance skills: Fallacies and guidelines. *Human Factors*, *27*, 285–301.

Slobounov, D., Yukelson, D., & O'Brien, R. (1997). Self-efficacy and movement variability of Olympic level springboard divers. *Journal of Applied Sport Psychology*, *9*, 171–190. doi:10.1080/10413209708406480

Stoffregen, T., Bardy, B., Smart, L., & Pagulayan, R. (2003). On the nature and evaluation of fidelity in virtual environments. In L. Hettinger & M. Haas (Eds.), *Virtual and adaptive environments: Applications, implications and human performance issues* (pp. 111–128). Mahwah, NJ: Lawrence Erlbaum Associates.

Wilson, C., Simpson, S., van Emmerick, R., & Hamill, J. (2008). Coordination variability and skill development in expert triple jumpers. *Sports Biomechanics*, *7*(1), 2–9. doi:10.1080/14763140701682983

Wrightman, D., & Lintern, G. (1985). Part-task training for tracking and manual control. *Human Factors*, *27*, 267–284.