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Original Article

Impact of the constraints-led approach on students' motor performance

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Abstract
To optimise motor skill acquisition, physical education learning design should beinformed by up-to-date motor learning theory. The Constraints-led Approach (CLA) is therefore a viable physical education teaching approach as its learning design and delivery of instruction is informed by the contemporary motor learning theory of ecological dynamics. **Problem Statement:**Critics have argued that more applied research studies are required to provide empirical evidence to support the efficacy of the CLA on motor performance. **Purpose:**The purpose of this study was tobuild on the current body of empirical evidence by investigating the impact of a constraints-led physical education lesson on the hurdling performance of university students. **Approach:**A total of 42 undergraduate university students voluntarily submitted the video recordings of their hurdling performance, before and after participation in a 40-minute, constraints-led hurdling lesson. To evidence any improvement in students' performance, three hurdling coaching experts were recruited to qualitatively assess the hurdling technique in each of the 84 randomly ordered video recordings. **Results:**Students' hurdling technique was presented as both averages across all three experts and for each individual expert. Intraclass correlation coefficient (ICC) and 95% confidence intervals were calculated to assess the interrater reliability across the three experts, based on a mean rating (k=3), two-way mixed model and absolute agreement. Intra-rater reliability was assessed by ICC and 95% confidence intervals, using a random sample of 15 video recordings rated a second time.The ICC for inter-rater reliability indicated good to excellent reliability or agreement among the expert coaches' ratings. The ICCs for intra-rater reliability indicating excellent reliability or consistency of each experts' individual ratings. Mean scores across all experts revealed that there was a significant difference in hurdling performance from pre to post intervention. **Conclusion:**The results from this study provide additional empirical evidence of the efficacy of the CLA in improving motor performance of students in a technically complex athletic event, strengthening its validity as a viable alternative pedagogy within the discipline of physical education.
Keywords: **physical education, skill acquisition, ecological dynamics.**

Introduction

An important learning outcome incorporated into physical education curriculum documents from around the world, is the development of students' motor skill competency (Australian Curriculum & Assessment Reporting Authority, 2014; Department for Education, 2013;Society of Health & Physical Educators, 2013). According to motor learning researchers, to optimally achieve this outcome,contemporary motor learning theory must inform the learning design and delivery of instruction in physical education (Chow et al., 2013; Davids et al., 2015; Renshaw et al., 2016). This is not the case with the traditional approach, the dominant teaching approach implemented worldwide by teachers of physical education (Cothran et al., 2005; Moy et al., 2014; SueSee et al., 2019).Its learning design has been proposed to be informed by behaviourism, a rather antiquated theoretical representation of the learning process(Hopper et al.,2009). Behaviourism typically takes a 'training' and 'mindless' approach to teaching and learning, emphasising the use of feedback, reward and punishment systems to modify behaviour (Light, 2008). The traditional approach has been criticised from a motor learning perspective because learners' involvement is restricted to imitation and the repetitive reproduction of teacher-prescribed and reinforced motor skill 'templates' in decontextualised drills, rather than allowing the learner to explore and discover their own functional movement solutions. An additional concern is that motor skills are practiced as decomposed sub-routines, which could impedethe coordination of perception and action (Renshaw et al., 2010; Williams & Hodges, 2005). These shortfalls highlight anobligationto investigate aphysical education teaching alternative, underpinned by more contemporary motor learning theory.

In recent times, motor learning researchershave proposed the Constraints Led Approach (CLA) (Newell, 1986), as a viable alternative physical education pedagogy to support the development of students' motor skill competency.From a practical perspective, the CLA challenges individual learners to actively explore

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representative and modified practice environments to implicitly solve technical and tactical movement problems (Renshaw et al., 2016). The CLA's learning design and delivery is informed by the principles of a nonlinear pedagogy (NLP), which incorporates the concepts of the contemporary motor learning theory of ecological dynamics, a theory that recognises the important role of the individual learner and the environment in motor skill acquisition(see Chow et al.,2011).These learning design principles are manipulation of learning environments using task constraints, representative learning design, task simplification, ensuring functional movement variability and instruction focused on the external outcome of a movement (Chow, 2013; Chow et al., 2016;Renshaw et al., 2009, 2016; Renshaw & Chow, 2019; Tan et al., 2012).From an ecological dynamics' perspective, when an individual's unique intrinsic dynamics (individual constraints) continuously interact with specific task demands (task constraints) and the physical and social environment environment (environmental constraints), the system self-organises into a temporarily stable state, and motor skills emerge implicitly (Araújo et al., 2017; Chow et al., 2011; Davids et al., 2008;Davids et al., 2015).For example, a swimmer's unique functional butterfly technique mightimplicitly emerge as a result of the continuous interactions between their shoulder flexibility (individual constraint), the distance to be covered (task constraint), and the temperature of the water (environmental constraint). Theconcept of self-organisation under interacting constraints challenges the misunderstanding that there is one optimal technique towards which all individuals should aspire, as individuals have the ability to self-organise in many diverse ways to achieve the same desired movement outcome (Davids, et al., 2008).

An important principle of the CLA is the learning of motor skills in an environment that is representative of the performance environment but simplified to a level that matchesan individual learner's capabilities (Brunswik, 1956; Pinder et al., 2011; Renshaw et al., 2016). The presence of key sources of information from the performance environment in the practice environment, such as an opponent,ensures that the relevant perception-action couplings are present, allowing individuals to coordinate what they do in response to what they see (Chow, 2013; Gibson, 1986; Renshaw &Chow, 2019; Tan et al., 2012). However, while it is important that practice is representative, to optimise motor skill development and transfer to the performance environment, practice task complexity should be simplified to match the individual technical ability of the learner (Davids et al., 2015; Moy, 2019; Renshaw &Chow, 2019; Renshaw et al., 2016). Practice tasks can be simplified by manipulating task constraints such as equipment, rules, and playing dimensions, while ensuring that the key information that guides movement is present (Renshaw et al., 2009).Within theframework of the CLA, learning occurs implicitly through exploration with teacher instruction directing the learners' attention onthe external outcome or result of a movement rather than on the movement itself (Wulf et al., 2002). Ecological dynamics has been shown to also providea suitable theoretical framework to underpin learning design in alternative physical education teaching approaches such asTeaching Games for Understanding (TGfU)(see Chow et al., 2016; Stolz & Pill, 2014).

There is extensive theoreticalresearch evidence in the motor learning literature to show that adopting the CLA learning design principles in practice can enhance an individual's motor performance (Chow, 2013; Renshaw & Chow, 2019; Renshaw et al., 2019). However, there is very little empirical research evidence to support the theory. One of these studies by Gray (2018) investigated the effectiveness of a 6-week CLA coaching intervention on modifying the technique of skilled baseball batters. The study found that using the task constraint of a barrier, and instructions focused on the external outcome of a movement,that is, 'attempt to hit the ball over the barrier', resulted in baseball batters increasing their launch angle and the number of fly balls and home runs hit. Fitzpatrick and colleagues (2018) manipulated task constraints during the coaching of young novice tennis players to afford more opportunities for backhands. Over the 8-weekcoaching intervention they found thatmanipulating task constraints,such as awarding bonus points if a participant hit a backhand winner, ameliorated the disparity between the percentage of forehands and backhands performed during match-play. Simultaneously, they found that greater backhand success ratesand enhanced technical proficiency emerged. Lee and colleagues (2014)manipulated task constraints over4 weeks of tennis training, such as court size, net height, and rules, and they used instructions that focused on the result or external outcomeof a movement, for example, 'hit ball flight likea rainbow shape'. They found that this learning environment improved the performance of young novice tennis players' forehand stroke. Komar and colleagues (2019) investigated the CLA's impacton the breaststroke performance of novice swimmers over 16 sessions. The research study found that instructions focused on the external outcome of a movement, that is, 'glide two seconds', promoted and guided exploratory learning. This resulted in the emergence of enhanced breaststroke performance among participants in the form of an increased stroke length while maintaining the same sub-maximal speed.

Some studies have manipulated task constraints to simplify the learning environment anddemonstrated that it can lead to adaptive changes that enhance children's motor performance. For example, researchers investigated the immediate effect of simplifying the game of tennis by scaling the size of a racquet, tennis court dimensions, net height, and ball compression in relation to the physical size of children. They found that these task simplifications created an enhanced learning environment for novice and skilled junior tennis players resulting in improved tennis performance, for example, more accurate placement of shots, a substantial increase in the number of clear winners, longer rallies, and a higher percentage of successful first serves(Buszard et al., 2014; Limpens et al., 2018; Timmerman et al., 2015).

Critics have argued that more applied research studies in pedagogical settingsare required to provide empirical evidence to support the efficacy of the CLA on motor performance (Renshaw et al., 2019). Hence, this study's aim is to build upon the existing body of empirical evidence through investigating the impact of a constraints-led physical education hurdling lesson on the motor performance of students in a university setting.The individual track event of hurdling was chosen for a variety of reasons. Firstly, no previous empirical studies have investigated an individual track and field event. Secondly, it was thought that improved performance in a motor skill with a complex coordination pattern like hurdling (Brown, 2013), would strengthen the findings. Thirdly, it was expected that university students would have very little experience in hurdling compared to other physical activities. This would allow sufficient scope forimprovement intheir motor performance, while replicating a typical school physical education lesson which would consist of many novice hurdlers.A final reason for choosing hurdling was that it is normally 'taught' in one 30-40-minute lesson in Australian schools as part of a track and field unit, making the study intervention length an authentic replication of physical education practice.

Based on the findings from previous empirical studies, it was predicted that participation in the hurdling lesson would result in an improvement in students' hurdling technique. This finding would be beneficial as further empirical evidence of enhanced motor performance outcomes in one of the more technically difficult athletic events, would strengthen the validity of the CLA as a viable alternative pedagogy compatible with current physical education curriculum learning outcomes.

Material & methods

Study design

In this study, a pre–post-test experimental design was adopted. This design was chosen as it can effectively address the aim of investigating the impact of an intervention, such as, an alternative physical education pedagogy on an outcome, such as motor performance.

Participants and context

The study participants were undergraduate Sport and Exercise Science, and Physical Education Teacher Education (PETE) students studying a first-year practical unit on the principles of coaching at a university in Australia. The unit incorporated a tutorial session that involved students investigating the impact of a constraints-led physical education lesson on their hurdling performance. In thissession students were initially required to complete a written questionnaire about their personal hurdling background, then, in pairs,filmeach other's hurdling technique using their mobile devices, before and after participation in a 40-minute constraints-led hurdling lesson. The students then analysed and evaluated their hurdling video recordings, as a means of investigating anyimprovement in their hurdling technique. It should be noted that this analytical task was not part of the study.

Prior to each of the five tutorial sessions within the unit,an independent colleague outlined the session structure to all students (n=120), emphasising that participation was a unit requirement.Students were informed that they could voluntarily submit their completed questionnaire and video recordings to the primary researcher after the tutorial class for use in a research study to investigate the impact of the learning event on hurdling performance. Students were informed that their completed questionnaire and video recordings would be identifiable only by code but not name, and that the video footage of their hurdling technique would only be viewed by researchers and assessed by hurdling coaching experts, as a means of evidencing any techniqueimprovement. Students were also informed that their decision to participate or not participate would in no way impact upon their unit grade.

The study sample (n = 42) consisted of students who consented to participate in the study by voluntarily submitting their completed questionnaire and video recordingsto the primary researcher. The sample consisted of 23(55%) males and 19 (45%) females. In relation to participants' hurdling background, as we had expected, 34(81%) participants did not have any experience in hurdling, 6 (14%) participants reported that either their school or club was their highest level of hurdle representation, and 2 (5%) participants were considered elite hurdlershaving represented their state.

The primary researcher and lead author, who was also a physical education teacher educator at the same Australian university, taught the hurdling lesson. He was well qualified for the role as he possessed over 25 years of experience teaching and coaching track and field in Australian schools, and 12 years of experience researching and applying the CLA within the university setting.

Pre-intervention

After participating in a thorough warm up of running over low obstacles and dynamic stretching, students filmed each other racing against two or three opponents of their choice over three flights of hurdles over 40 metres. This race distance was chosen as it was long enough to allow an accurate assessment of hurdling technique and short enough to allow students to run 'fast' or 'flat out' for the entire distance, minimising any impact of fatigue on their performance. Twelve lanes were set up, each lane consisting of three hurdles that were set at the same interval distance and height. Through the twelve lanes, the hurdle height and interval distance progressively increased (see Table 1), ranging from Athletics Australia's hurdle specifications for 10 and 11-year-old boys and girls (lane 1), to 16-year-old boys and Open girls (lane 12). This gave students multiple hurdling options of varying complexity to allow for any individual differences among the group. Students self-selected the lane they ran in, based on their perceived current hurdling ability.

Table 1 Hurdle interval and height for each lane

LANE	INTERVAL (m) 13 metres to first hurdle	HEIGHT (cm)
1	**5**	**60**
2	**5.5**	**60**
3	**6**	**60**
4	**6**	**68**
5	**6.5**	**68**
6	**6.5**	**76**
7	**7**	**68**
8	**7**	**76**
9	**7.5**	**76**
10	**7.5**	**84**
11	**8**	**84**
12	**8.5**	**84**

Intervention

The key learning design principles of a NLP informed the learning design and delivery of instruction of the constraints-led hurdling lesson. The lesson comprised of two learning experiences. The first learning experience sought to facilitate students' development of a hurdling rhythmusing low obstacles. Three mini hurdles of 30 cm height were set out in each of 6 lanes. Each lane of mini hurdles was set at a progressively longer interval distance, ranging from 5 metre intervals in lane 1 to 7.5 metre intervals in lane 6. Students commenced practice in a lane of their choice. While students practiced, the teacher did not provide any explicit verbal instruction in relation to the internal body movements required to achieve the 'ideal' hurdling technique (i.e., the 'how to do it'). Instead, the teacher provided students with two specific instructional constraints, each focused on the external outcome of a movement, specifically,'try to get 3 steps in between each hurdle' and 'try to run fast over the hurdles'.Students were given sufficient time to explore the environment anddevelop a hurdling rhythm. When able to accomplishthe 3-step outcome in their chosen lane, students were challengedto progress through the remaining lanes of increasing intervals.This activity lasted approximately 10 minutes.

Within a CLA, learning environments simulate representative performance environments, thus,the second learning experience sought to facilitate the development of students' hurdling technique by practicing over 3 flights of hurdles over 40 metres in race like conditions. The hurdles were set out as listed in Table 1 and students were given the choice of lane in which to commence 'racing'. Students were again allowed time to explore the learning environment, while being reminded of the task instructions introduced previously. When able to accomplishthe 3-step outcome in their chosen lane, students were challengedto progress through the remaining lanes of increasing intervals. To minimise fatigue, students were instructed to rest for 2-3minutes in between practice attempts. This activity lasted approximately 30 minutes.

Post-intervention

After the hurdling lesson, students filmed each other racing against two or three chosen opponents in their preferred lane over three flights of hurdles over 40 metres. Participation in a second race allowed for an accurate comparison of hurdling technique from before to after participation in the constraints-led hurdling lesson intervention. It was noted that the majority of students chose a more difficult lane for their second race.

Authenticity of the CLAlearning design and delivery

When investigating outcome measuresrelated to the implementation of an alternative pedagogy, it is imperative that the learning design and delivery of instruction authentically represents that pedagogy (Hastie & Casey, 2014).The constraints-led hurdling lesson was designed and implemented by the primary researcher, who possessed extensive knowledge and experience in constraints-led physical education learning design to expect an authentic representation of thatpedagogy. The lesson content was reviewed by an academic colleague with a significant CLA research and publication record, who subsequently verified its authenticity in accurately representing the CLA. This study used a method adopted in similar studies to establish acceptable fidelity of the implementation of the CLA (Harvey et al., 2010). In each of the five hurdling lessons conducted by the primary researcher, an expert independent observer viewed and validated the hurdling lesson usinga checklist to verify that the CLA's key operational and pedagogical principles were present in the lesson (see Table 2). Implementing this process enabled the primary researcher to be confident that all of the hurdling lessonsauthentically represented the key features of the CLA.

Table 2 CLA lesson observation checklist (adapted from Chow, 2013; Chow et al., 2016; Renshaw et al., 2016).

Key Operational and Pedagogical Requirements of the CLA	√
Practice Task Environment Representative of Performance Environment:	
• Key information sources present (coordinate information/perception & movement/action)	
• Subcomponents practised together	
Task constraint manipulation to:	
• Simplify environment (hurdle height and interval)	
Exploratory Facilitation (self-organisation)	
• Learners given the time to actively explore the learning environment	
• Problem solving behaviour is allowed to implicitly emerge	
Teacher Instruction and Feedback:	
• Performance outcome aligned (tell students what to do, not how to do it)	
• Focused on the external outcome of a movement	

Data collection

To evidence any potential improvement in students'performance, three hurdling coachingexperts were recruited to assess the video footage of participants' hurdling technique,recorded before and after participation in the CLA hurdling lesson. The experts' combined hurdling coaching experience totalled 60 years (expert 1= 25 years, expert 2= 28 years, expert 3=7 years). They had all coached athletes with varied hurdling abilities, ranging from school through to state, national and international level. One expert was a former international level hurdler.

Codes were removed from the 84 hurdling video recordings (42 pre-intervention and 42 post-intervention) andwere randomly ordered to ensure that each recording was assessed in isolation of its partner. A USB flash drivestoring the video recordings was given to each hurdling coaching expert, along with a sheet to record each of their 84 assessments. Each expert was asked to rate how much each students' technique look like 'proper' hurdling, using a 5-point Likert scale (1 = not at all; 2 = very little; 3 = somewhat; 4 = very much; 5 = completely). Experts were also supplied with video examples of what the research team deemed was a hurdling technique representative of each scale value.

A potential limitation in terms of obtaining a representative sample of hurdling ability levels, was that only students who believed they were competent hurdlers would voluntarily submit a video of their performance to the researchers. However, the study sample represented a variety of ability levels as evidenced by the three coaching experts' rating of their pre-intervention hurdling technique, that is, 6 (14%) participants received a rating of 2, 21 (50%) participants received a rating of 3, 13 (31%) participants received a rating of 4, and 2 (5%) participants received a rating of 5. The sample make-up in terms of the range of ability levels was determined to be an accurate reflection of student ability levels in a typical physical education class.

Data analysis

Intraclass correlation coefficient (ICC) and 95% confidence intervals were calculated to assess the interrater reliability across the three experts, based on a mean rating (k=3), two-way mixed model and absolute agreement (Koo &Li, 2016). Where a high ICC was found, difference in hurdle performance pre to post intervention would be assessed using Wilcoxon Sign Ranks Tests, using the mean score across all three experts. Additional analysis would assess differences for each individual expert. Intra-rater reliability was assessed by ICC and 95% confidence intervals, using a random sample of 15 hurdling video recordings rated by each expert for a second time, one week after their initial assessment.

Descriptive statistics were used to present characteristics of the participants. Descriptive statistics for hurdling performance are presented as both averages across all three experts and for each individual expert. All statistical analyses were conducted in SPSS version 23.0 (IBM Corporation, Armonk, NY, USA). P-values were based on two-sided tests and were considered statistically significant at $p<0.05$.

Results

Reliability

The ICC for inter-rater reliability was 0.84 (95% CI = 0.73-0.91) indicating good to excellent reliabilityor agreement among the expert coaches' ratings (Koo &Li, 2016). The ICCs for intra-rater reliability were 0.88 (95% CI = 0.66-.096), 0.92 (95% CI = 0.78-.097), and 0.92 (95% CI = 0.78-.097), for expert 1, 2 and 3, respectively, indicating excellent reliability or consistency of each experts' individual ratings (Koo &Li, 2016).

Hurdling performance

Mean scores for hurdle performance are displayed in Table 3. Scores across all experts revealed that there was a significant difference in hurdlingperformance from pre to post intervention ($Z=3.90$, $p<0.001$). When experts were considered individually, there were also significant differences from pre to post instruction for expert 1 (Z=2.76, p<0.01), expert 2 (Z=3.27, p<0.001), and expert 3 (Z=4.19, p<0.001).

Table 3 Mean hurdle performance scores, pre and post CLA hurdling lesson intervention

	Average pre	Average post	Expert 1 pre	Expert 1 post	Expert 2 pre	Expert 2 post	Expert 3 pre	Expert 3 post
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
HP score (n=42)	3.3 (.7)	3.8 (.6) *	3.3 (.7)	3.7 (.6) *	3.6 (.8)	4.0 (.7) *	2.9 (.8)	3.6 (.8) *

HP = hurdle performance; * indicates significant difference p<0.01.

Discussion

The study aim was to investigate the impact of a constraints-led physical education lesson on the motor performance of university students, measured using the analysis of their hurdling technique. As predicted, participation in the constraints-led hurdling lesson resulted in a significant improvement in students' hurdling technique. These results considerably build on the current body of empirical evidence to support the efficacy of the CLA on enhancing motor performance. This is because of the significant improvement in participants' performance of a motor skill with a complex coordination pattern, after participation in just one 40-minute constraints-led lesson. These results are consistent with previous empirical research studies that have provided evidence to support the efficacy of a CLA on motor performance, over much longer intervention periods and in activities with less complex coordination patterns (Buszard et al., 2014; Fitzpatrick et al., 2018; Gray, 2018; Lee et al., 2014; Limpens et al., 2018; Timmerman et al., 2015). The theoretically basedprinciplesthat inform the CLA's learning design and delivery of instruction can logically explain the results and thus provide the framework for the following discussion.

The manipulation of learning environments using task constraints

The NLP principle of manipulation of task constraints to match the current intrinsic dynamics of each individual learner can explain the improvement in hurdling technique. This principle is underpinned by the understanding that an individual's technique emerges from the continuous interaction between key constraints, that is, their unique individual characteristics, the task requirements, and the environment (Chow, 2013, Chow et al., 2016). In the hurdling lesson, the task constraints of hurdle interval and hurdle height were manipulated, and participants were encouraged to explore the practice environment. Each participant's unique hurdling technique therefore emerged as a result of the continual interaction between their distinctive individual constraints (e.g., lower back and hamstring flexibility), the task constraints (e.g.,the height of hurdles) and the environmental constraints (e.g., the strength of the headwind) imposed on them. Adopting thelearning design principle of constraint manipulation in the CLA hurdles lesson afforded participants the freedom to explore hurdling techniquesover multiple practice options of varying difficulty, allowing their most functional hurdling technique to emerge.

Representative learning design/Task simplification

The principles of representative learning design and task simplification can help explain the improvement in students' hurdling technique. A key concept of ecological dynamics is acknowledging that an individual's actions and their perceivedenvironment are mutually interdependent (Gibson, 1986). In simple terms, what an individual does (their action) is tightly coupled or coordinated with the key information they see in the environment (their perception), and what they see is a result of what they have done.In the constraints-led hurdling lesson, the second practice task was representative of a hurdles race, that is, running 13 metres to the first hurdle, followed by running over two successive hurdles. Adopting this representative practice design provided participants with authentic opportunities to learn to successfully couple or coordinate their movements (e.g.,the take-off of their lead leg) with the same key information they would perceive in the performance environment (e.g., their distance from the hurdle).

Rather than the traditional approach of separately practicing the sub-components of the hurdling action to make the motor skill easier for the learner (see Moy et al., 2016), in the constraints-led lesson the sub-components of the complex hurdling action were practiced together, that is, lead leg and trail leg in tandem with the upper body but in a simplified environment.Practicing in a simplified environment with multiple practice options of varying levels of difficulty, allowed participants the opportunity to explore and discover the hurdle height and interval that best matched their unique individual characteristics, allowing their most functional hurdling technique to emerge (Renshaw et al., 2016).These results are consistent with previous research findings of enhanced tennis technical performance when task constraints, such as net height, were manipulated to simplify the task to match novice junior players' unique individual characteristics, specifically their physical size (Buszard et al., 2014; Limpens et al., 2018; Timmerman et al., 2015).

Instructions focused on the external outcome of a movement

Within the nonlinear framework of the CLA, learning occurs implicitly through the process of exploration with feedback self-generated (Beek,2000; Jackson &Farrow,2005). Exploration is facilitated by using instructions that focus a learner's attention on the external outcome or result of a movement, rather than focusing on the mechanics of the movement itself (Peh et al., 2011). Instructions with an external focus minimise the conscious control of body segments thus allowing the learner's most functional movement solutions to emerge implicitly (Masters, 2013). In the constraints-led hurdling lesson, participants were provided with instructions that focused their attention on the external outcome of a movement, for example, 'try to get 3 steps in between each hurdle' and 'try to run fast over the hurdles'.Focusing on these external outcomes, facilitated participants' exploration of the hurdling action. This enabled them to implicitly discover their own unique hurdling solution to best achieve the prescribed external outcomes.

Research has consistently found thatinstructions that generate an external focus, when compared to instructions that generate an internal focus, result in more effective performance and learning of a variety of motor skills in individuals of varying ability levels (for reviews, see Wulf, 2012).For instance, studies have exhibited the motor performance or motor learning advantages of external focus instructions for discrete sports skills, such as basketball free-throw shooting (Al-Abood et al., 2002), golf ball hitting accuracy (Wulf &Su, 2007), swimming (Freudenheim et al., 2010), long jumping (Porter et al., 2010),soccer kicking (Wulf et al., 2002), and volleyball serve reception (Lola &Tzetzis, 2020). The results of this study are consistent with previous CLA empirical research findings of enhanced motor performance in baseball, breaststroke swimming and tennis, when task constraint manipulation was combined with instructions focused on the external outcome of a movement (Gray, 2018; Komar et al., 2019; Lee et al., 2014).

Study limitations and future research

Although the study findings build on the existing evidence base of the CLA, there is a limitation that restricts the extent to which the findings can be applicable to otherpedagogical settings.It is acknowledged that the sporting profile of undergraduate PETE and Sport and Exercise Science participants could arguably be significantly different to the sporting profile of students within a standard physical education class. To address this limitation, future study could investigate the impact of the CLA on the motor performance of individual physical education students inprimary and secondary school physical education classes.

Conclusion

This study has provided additional empirical evidence to support the efficacy of the CLA in improving students' motor performance. Participants' significant improvement in the technically complex athletic event of hurdling, in just one 40-minute constraints-led lesson, strengthens the validity of the CLA as a feasible alternative physical education teaching approach. The CLA presents physical education practitioners worldwide with a pedagogyinformed by the contemporary motor learning theory of ecological dynamics, that effectively meets the important physical education curriculum learning outcome of developing students' competency in motor skills.

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