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Design of a Theory-Informed Virtual Reality Training Programme for Motor Skill Development in Physical Education: Structure, Progression and Feedback

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Abstract—

Virtual reality (VR) is increasingly proposed for physical education, but many programmes are described only by the equipment or game used, which makes them difficult to evaluate or reproduce. This paper presents the design of a structured VR-supported training programme for balance, coordination, visual response, movement accuracy and object control in school physical education. The design links five motor-learning ideas—stages of skill acquisition, schema theory, the constraints framework, the OPTIMAL theory and contextual interference—to concrete programme features. The programme comprises 24 supervised 30-minute sessions over eight weeks. Each session combines about 10 minutes of VR practice with 10 minutes of linked physical practice, giving 240 planned minutes in each mode. A matched conventional programme addresses the same objectives in the same time. Progression follows four two-week phases and an individual rule: a student advances after at least 8 correct responses out of 10 in each of two observation blocks and is moved to a simpler task after fewer than 6. Binomial analysis shows that this rule advances a student with a true success rate of 90% with probability 0.86, but one at 70% with only 0.15, so it is conservative for students near the threshold. Feedback separates task outcome from movement quality and is gradually reduced. Safety, comfort and fidelity checks are specified for every session. The design provides a reproducible intervention that can be tested for real-world transfer and retention; it reports no participant outcomes.

Index Terms—*Virtual reality, physical education, motor skills, motor learning, programme design, feedback, skill progression, balance, coordination*

1. Introduction

Motor competence underpins participation in games, sport and everyday physical activity, and it is linked with physical activity across childhood and adolescence [1]. Physical education (PE) is the main setting in which most young people receive structured practice of these skills. However, students differ in ability, experience and confidence, and a single lesson format rarely provides the right amount of practice, feedback and challenge for everyone.

Virtual reality offers an interactive environment in which tasks can be repeated, adjusted in difficulty and accompanied by immediate feedback. Immersive environments can also produce realistic responses because users behave as if the situation were real [2]. These features make VR attractive for teaching movement, but they do not guarantee learning. Reviews of VR motor training emphasise that improvement in a virtual task does not necessarily transfer to the physical skill, and that transfer depends on how closely the virtual task matches the real one and how practice is organised [3], [4].

Recent school studies report benefits of VR activities for balance and coordination [5] and of VR combined with gamification in PE [6]. Yet published programmes are often described mainly by their hardware and software, with little detail about session structure, progression or feedback. Without such detail, results cannot be reproduced or attributed to a specific design. This paper, derived from a doctoral thesis, makes three contributions:

1) A mapping from five motor-learning theories to specific features of a VR-supported PE programme.
2) A complete programme specification: session structure, dose, four-phase progression, matched comparison activities and an individual progression rule.
3) A quantitative analysis of the progression rule, together with feedback, safety and fidelity procedures for delivery in schools.

2. Theoretical Background

2.1 Motor Learning Theories

Skill acquisition is often described as moving from an early stage, in which the learner works out what the task requires, towards more consistent and automatic control. Schema theory proposes that varied practice builds generalised rules linking movement parameters to outcomes, which supports performance in new variations of a task [7]. The constraints framework explains movement as emerging from interactions between the learner, the task and the environment, so teachers can

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shape learning by changing task rules or conditions [8]. The OPTIMAL theory links enhanced expectancies, autonomy and an external focus of attention to better performance and learning [9]; an external focus on the movement effect generally benefits learning more than attention to body movements [10]. Contextual interference research shows that mixed practice can reduce performance during practice but improve retention and transfer [11].

2.2 Feedback and Immersive Learning

Augmented feedback can speed learning, but frequent concurrent feedback may create dependence and weaken performance when it is removed [12]. VR systems often provide continuous feedback by default, so feedback must be planned rather than accepted as delivered by the software. Immersive environments can also increase cognitive load, and higher presence does not automatically produce better learning [13]. Head-mounted displays may cause discomfort or cybersickness, which must be monitored [14].

2.3 From Theory to Programme Features

Fig. 1 and Table I show how each idea was translated into the design. The theories are used as guides to task design and instruction, not as a single combined model, and none of them establishes by itself that the programme will be effective.

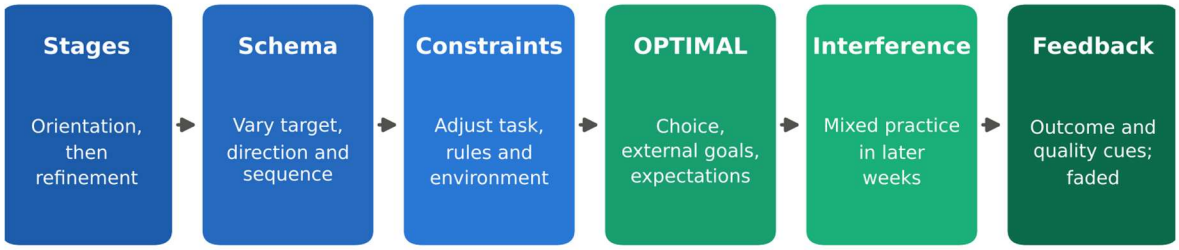

Fig. 1. Motor-learning ideas used to design the VR-supported programme and the programme feature each one informs.

TABLE I THEORETICAL IDEAS AND THEIR USE IN THE PROGRAMME

Theoretical idea	Main contribution	Programme feature	Caution
Stages of acquisition	Changes in task understanding and control	Orientation phase, then refinement and progression	Stages are not fixed age categories
Schema theory [7]	Adaptable rules from varied experience	Vary target position, direction and sequence	Variation must relate to the intended skill
Constraints [8]	Movement emerges from learner, task and environment	Adjust targets, rules and practice conditions	The headset itself changes task demands
OPTIMAL theory [9]	Motivation and attention support learning	Limited choice; external goals; positive expectations	Enjoyment alone does not show learning
Contextual interference [11]	Practice success differs from later adaptability	Mixed practice in weeks 5–8	More difficulty is not always better

3. Programme Design

3.1 Participants, Setting and Equipment

The programme is designed for school PE students aged about 13 to 14 years. It requires standalone head-mounted displays with hand controllers and inside-out tracking, an age-appropriate application whose tasks match the movement objectives, and a clear practice area separated from the physical-practice stations. The equipment model, software version, permitted adaptations and supervision ratio are fixed in an intervention manual before delivery, following the TIDieR checklist for describing interventions [15]. No application is assumed to train the intended movements simply because it is marketed as a sports game.

3.2 Session Structure and Dose

The programme consists of three supervised 30-minute sessions per week for eight weeks, giving 24 sessions and 720 planned minutes (Fig. 2). Each session has a 5-minute warm-up, 20 minutes of targeted practice and a 5-minute cool-down with reflection. In the VR-supported group, the targeted period is split into about 10 minutes of VR practice, which may be divided into shorter bouts for comfort, and 10 minutes of physical practice linked to the same skill. Across the programme this provides about 240 planned minutes in each mode. Planned minutes are opportunities, not achieved exposure; active time, rest, transitions and technical delays are recorded separately.

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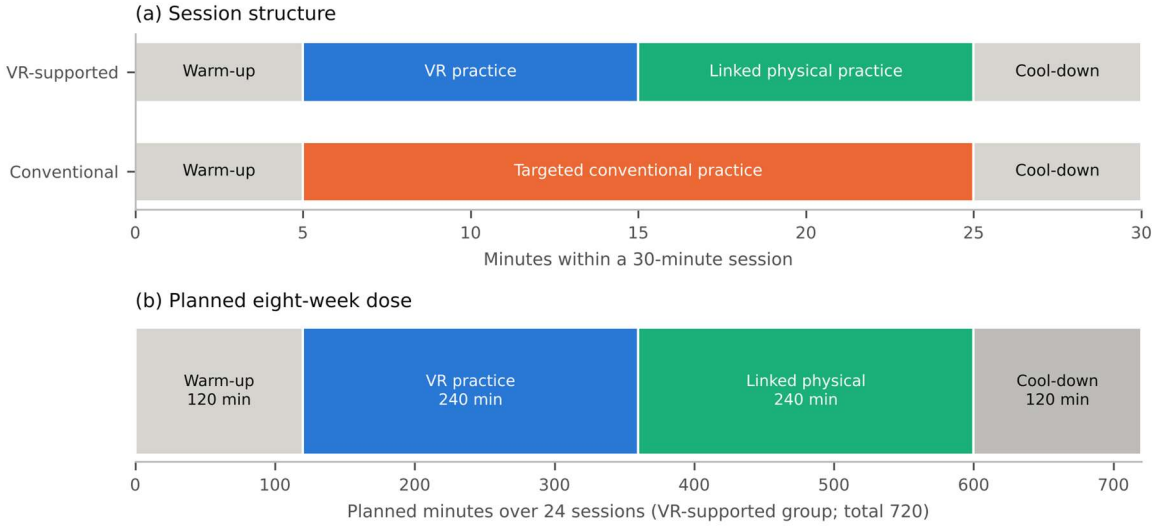

Fig. 2. (a) Structure of a 30-minute session in the VR-supported and conventional groups. (b) Planned distribution of the 720 programme minutes in the VR-supported group.

3.3 Training Activities and Matched Comparison

Table II lists the training activities. Each VR activity is paired with a physical activity that practises the same demand under ordinary vision, so that students connect the virtual task with the real movement. Physical practice uses layouts that differ from the assessment tasks, so the programme does not rehearse the tests. The comparison group receives conventional activities with the same objectives, the same time and comparable feedback and choice, so that any difference between groups can be attributed to the use of VR rather than to extra practice or attention.

TABLE II TRAINING ACTIVITIES AND MATCHED CONVENTIONAL ACTIVITIES

Learning objective	VR-supported activity	Linked physical practice	Conventional comparison
Stable reaching	Controlled reach and return to virtual targets	Reach to physical markers	Reach to visible physical markers
Directional control	Reach to targets in changing directions	Directional reaching without the test layout	Adjusted physical target positions
Coordination	Alternating virtual hand sequences	Simple arm and step sequences	Teacher-led arm and step sequences
Visual response	Select the correct action to a virtual cue	Respond to teacher-presented cues	Respond to teacher-presented signals
Aiming	Simulated target task	Soft-ball throws at practice targets	Soft-ball throws at physical targets
Integration	Mixed familiar tasks with variation	Combined skills without test rehearsal	Combined conventional skill practice

3.4 Weekly Organisation and Four-Phase Progression

Each week contains three session types: A for balance, B for coordination and response, and C for integration. Over eight weeks, the programme moves through four two-week phases (Fig. 3). In weeks 1–2 tasks use a stable base and large, slow, predictable targets. In weeks 3–4 one demand at a time is changed. In weeks 5–6 two-choice cues and mixed arrangements introduce contextual interference [11] and invite self-correction. In weeks 7–8 students consolidate familiar skills with greater independence. Adaptive increases in difficulty have supported transfer in virtual sports training [16], but the calendar guides the activities available rather than forcing every student to the same level.

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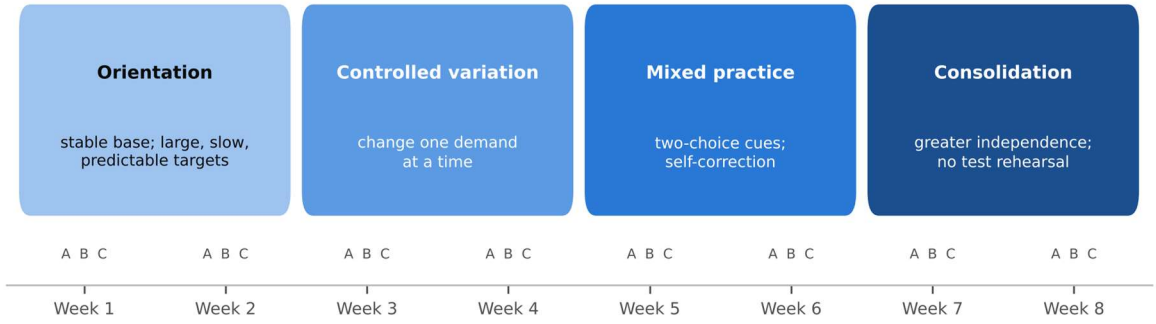

Fig. 3. Eight-week phase plan. Each week contains session types A (balance), B (coordination and response) and C (integration).

4. Individual Progression Rule

4.1 Decision Rule

Within each phase, a student advances to a harder task after at least 8 correct responses in each of two 10-attempt observation blocks across two consecutive attended sessions, provided that movement control is acceptable and there is no discomfort. A student is moved to a simpler task after fewer than 6 correct responses in a block, repeated loss of control or inability to explain the task; otherwise the level is maintained. A correct response must include the intended movement; points earned through shortcuts that the software accepts do not count. Discomfort overrides all numerical rules.

4.2 Behaviour of the Rule

If attempts are treated as independent with a true success probability p, the number correct in a block is binomial, $X \sim \mathrm{Bin}(10, p)$. The probabilities of each decision are

$$P_{\mathrm{adv}} = [P(X \geq 8)]^2, \quad P_{\mathrm{simp}} = 1 - [P(X \geq 6)]^2 \qquad (1)$$

with the remaining probability assigned to maintaining the level. Fig. 4 shows the result. A student who succeeds on 90% of attempts advances with probability 0.86, and one at 95% with 0.98. At 80%, the probability is only 0.46; at 70%, it is 0.15, with a 0.28 chance of being simplified. Students at 60% are simplified with probability 0.60. The rule is therefore conservative: it moves on only students who are clearly secure, and students near 80% may need several sessions to progress. This favours movement quality over speed of progression, but it should be checked in a pilot to ensure that students are not held at one level so long that motivation falls.

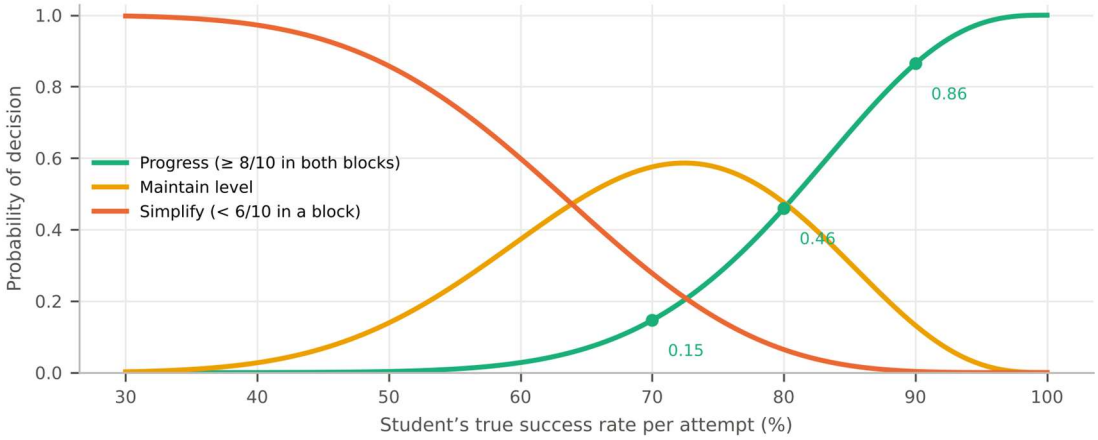

Fig. 4. Probability of each progression decision as a function of a student's true success rate per attempt (Eq. 1), assuming independent attempts.

5. Feedback, Safety and Fidelity

5.1 Feedback Strategy

Feedback distinguishes task outcome, such as a target changing colour, from movement quality, such as remaining stable during a reach. The software reports outcomes; the teacher adds information about quality. Instructions are short and directed at the movement effect, for example "guide the marker into the target", in line with evidence for an external focus [10]. Early

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sessions include demonstrations and brief corrections. As students understand the task, teacher prompts are reduced and students are asked to judge their own performance, to avoid dependence on augmented feedback [12]. Limited choice between two approved tasks provides autonomy without turning the programme into free game selection [9]. Public leaderboards are avoided.

5.2 Safety and Fidelity Checks

Table III lists the checks made in every session. Comfort is checked after fitting, between VR bouts and at the end of each session, because head-mounted displays can cause discomfort [14]. Delivery fidelity is recorded in both groups, and an independent observer reviews about 20% of sessions.

TABLE III SAFETY, ACCESSIBILITY AND FIDELITY CHECKS

Check	Required action	Evidence recorded
Readiness	Confirm willingness, fit, task understanding and starting position	Completed check and adaptations
Environment	Inspect floor, boundaries, cables and separation of stations	Dated setup checklist
Comfort	Check after fitting, between bouts and at the end; pause or stop if needed	Symptoms, timing, action and outcome
Movement quality	Judge the intended action, not software success	Quality criterion and teacher note
Progression	Apply the approved rule; change only permitted demands	Task level, blocks and reason
Dose	Separate attendance, opportunity, active time, rest and delay	Session sheet and device data
Fidelity	Delivery checklist in both groups; ~20% independent observation	Checklists and deviations

6. Discussion

6.1 Contribution of the Design

The programme makes explicit the decisions that determine whether VR practice can transfer to physical skills: how virtual tasks are linked to real movements, how difficulty changes, how feedback is reduced and how the comparison group is matched. Because these elements are specified in advance, a later evaluation can attribute its results to a defined intervention [15]. Pairing every VR activity with physical practice addresses the main limitation reported in VR training research, namely that skills learned in a virtual environment may not carry over to the real one [3], [4].

6.2 Practical Considerations

Delivery requires headsets, a safe practice area and staff trained to supervise both VR and physical stations. Short VR bouts limit discomfort and allow headsets to be shared, but transitions reduce active time, which is why active minutes are recorded separately from planned time. The progression rule requires teachers to observe and record 10-attempt blocks; simple checklists or software logs can reduce this burden.

6.3 Limitations

This paper describes a design and reports no participant data. The progression thresholds are decision rules to be checked in a pilot, not validated mastery criteria, and the binomial analysis assumes independent attempts with a constant success rate. The suitability of particular applications and the comfort of students must be confirmed before use.

7. Conclusion and Future Work

This paper presented a theory-informed VR-supported programme for motor skill development in physical education, comprising 24 sessions that combine VR and linked physical practice, a four-phase progression, a conservative individual progression rule, planned feedback reduction and detailed safety and fidelity checks. Future work will pilot the programme to refine timing and progression thresholds, then evaluate it against matched conventional instruction in a randomised trial with real-world transfer and retention outcomes.

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