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Beyond Reaction Time: From Data to Pedagogical Feedback in Motor Learning

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Abstract: Digital technologies in sport and physical education generate increasing amounts of performance data, yet their pedagogical value depends less on data volume than on how data are turned into meaningful feedback. This conceptual paper reframes light-based interactive technologies, such as BlazePod, from performance-oriented instruments into educational tools embedded in a formative feedback cycle. Drawing on models of engagement, feedback and self-regulated learning, it operationalises behavioural, cognitive, emotional and agentic engagement within technology-mediated motor tasks, treating device-generated indicators as information that supports awareness, strategic adjustment and self-regulation rather than as evaluative scores. It then presents the protocol of a two-arm feasibility pilot study with 40 to 60 adult athletes, comparing a structured sequence (interactive task, immediate feedback, guided reflection and re-attempt) with an equivalent condition using the same equipment without structured feedback. Feasibility criteria, measures, fidelity procedures and an analysis plan are pre-specified. The contribution offers a transferable framework through which coaches and physical educators can integrate digital data into formative assessment and instructional design.

Keywords: technology-enhanced feedback; athlete engagement; self-regulation; formative assessment; sport education.

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1. Introduction

Wearable devices, motion-tracking systems and interactive light-based technologies give coaches and teachers immediate access to data on movement, response time and accuracy, and monitoring models are increasingly used to assess physical activity against health recommendations (Ceruso et al., 2024). New tools are often evaluated mainly for their effects on physical performance (Cusano, Giardullo, et al., 2025). Their educational significance, however, cannot be inferred from their capacity to generate data: recent systematic evidence shows that the pedagogical value of digital tools depends on how data are interpreted and used rather than on the amount of information produced (Müller & Wagner, 2026).

This question lies at the core of *engaging education*. Engagement is neither a fixed trait of the learner nor an automatic effect of technological novelty; it emerges from the interaction between learners, tasks, feedback processes and environments. A device that captures attention through lights and speed may produce a short-lived novelty effect, or it may support durable engagement if its output is embedded in coherent instructional design.

Light-based systems such as BlazePod exemplify this tension. Developed for athletic training, they record reaction time, hits and errors, and their response-time measures show acceptable test–retest reliability (de-Oliveira et al., 2021). They belong to a broader family of technology-supported approaches to attention, speed and decision-making in motor learning (Cusano et al., 2022). The same data, however, can become information that helps athletes recognise a change, identify a difficulty and modify their next response, provided that the coach designs the conditions for this transformation.

This conceptual paper, accompanied by a study protocol, proposes a framework linking engagement dimensions, an instructional sequence and coaching actions (Section 2), presents the protocol of a feasibility pilot study (Section 3) and discusses pedagogical implications and limitations (Section 4). Empirical data will be collected in a subsequent phase.

2. Theoretical Framework

2.1. Feedback and Self-Regulation

Motor learning research distinguishes intrinsic feedback, available through the learner's own senses, from augmented feedback provided by an external source; reaction time and hit accuracy recorded by light-based devices are forms of knowledge of results. More feedback, however, is not necessarily better: according to the guidance hypothesis, frequent and immediate feedback can improve practice performance while weakening retention, because learners come to rely on the external source and neglect their own error detection (Salmoni et al., 1984). This is directly relevant to devices that return data after every trial by default. The OPTIMAL theory further shows that enhanced expectancies, autonomy and an external focus of attention jointly support learning (Wulf & Lewthwaite, 2016).

In educational research, feedback is information that reduces the gap between current and desired performance, and feedback on the task, the process and self-regulation supports learning more than feedback directed at the self (Hattie & Timperley, 2007). Formative assessment frames feedback as part of a cycle (where the learner is going, where they are now and how to get there; Black & Wiliam, 2009), and good feedback practice should strengthen learners' capacity to self-regulate (Nicol & Macfarlane-Dick, 2006). Its counterpart is teacher feedback literacy, the capacity to design feedback processes that learners can actually use (Carless & Winstone, 2023). In Zimmerman's (2002) cyclical model, self-regulated learning unfolds through forethought, performance and self-reflection. These strands converge on one principle: device-generated data become educational when they are selected, framed and followed by an opportunity for the learner to interpret and act on them.

2.2. Engagement as a Multidimensional Construct

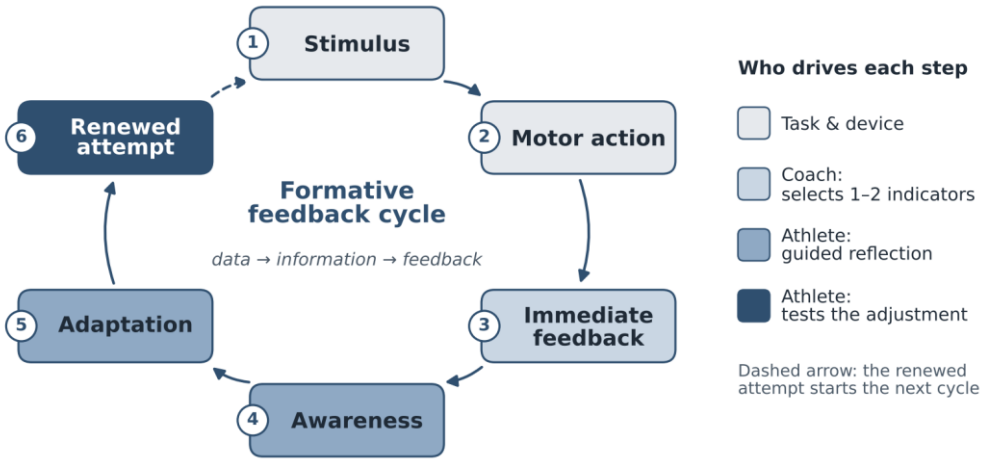
Engagement comprises behavioural, cognitive and emotional dimensions (Fredricks et al., 2004), to which Reeve and Tseng (2011) add an agentic dimension: learners' proactive contribution to the flow of instruction. In sports training, playful task design has also been associated with motivation and engagement (Di Lascio et al., 2026). The agentic dimension describes precisely what formative feedback aims to elicit, namely a learner who uses information to influence what happens next. The

four dimensions are treated here as interdependent components of a broader process; from a holonic perspective, each keeps a degree of autonomy while contributing to the whole (Cusano, Dumontet, & Ali Jarwar, 2025).

2.3. The Proposed Framework

The framework is organised around a six-step sequence (Figure 1): stimulus, motor action, immediate feedback, awareness, adaptation and renewed attempt. Task and device provide the first two steps; in the third, the coach selects which indicators to show, avoiding information overload; brief guided reflection supports the fourth and fifth, as the athlete identifies what changed, where errors occurred and what to do differently; the sixth closes the loop with an immediate opportunity to test the adjustment. On the scale of a single drill, the sequence mirrors the phases of self-regulated learning (Zimmerman, 2002), and feedback has an informational rather than judgemental function.

Figure 1. The six-step formative feedback cycle within a technology-mediated motor task.



Note. Steps 1–2 are provided by the task and the device, step 3 by the coach, and steps 4–6 by the athlete through guided reflection and a renewed attempt.

Table 1 links the four dimensions to indicators and coaching actions. Emotional engagement is assessed with the Interest/Enjoyment and Perceived Competence subscales of the Intrinsic Motivation Inventory (IMI; McAuley et al., 1989), consistent with self-determination theory (Ryan & Deci, 2020); emotional processes also shape cognitive processes in sport (Troisi Lopez et al., 2020). The framework is not a measurement scale but a heuristic for instructional design: for each dimension, the coach can ask which indicator is informative and which action it should trigger.

Table 1. Dimensions of engagement within technology-mediated motor tasks.

Dimension	Educational meaning	Possible indicators	Coaching action
Motor/behavioural engagement	Active participation, intensity and persistence	Stimuli reached, response time, persistence across trials	Adjust pace, stimulus distribution and difficulty
Cognitive engagement	Attention, decision-making and strategic processing	Accuracy, errors, adaptation to increasing complexity	Progress from predictable to unpredictable tasks
Emotional engagement	Enjoyment, interest and perceived competence	IMI Interest/Enjoyment and Perceived Competence subscales	Informative feedback, differentiation, achievable challenge
Agentic engagement	Active use of feedback to influence subsequent learning	Strategic adjustment, choices, changes between attempts	Guided reflection, opportunity for re-attempt

Note. IMI = Intrinsic Motivation Inventory.

3. Materials and Methods: Protocol of a Feasibility Pilot Study

3.1. Aims and Propositions

The study examines whether immediate technology-enhanced feedback, embedded in a structured sequence, supports engagement and self-regulation beyond motor performance. The primary aim is to assess the feasibility of recruitment, retention, adherence, intervention fidelity and data collection in ordinary training settings (criteria in Section 3.4).

Three exploratory propositions will inform a subsequent, adequately powered trial:

- **P1.** Athletes following the complete sequence will report higher overall engagement than athletes performing equivalent tasks without structured feedback;
- **P2.** The difference will be most evident for agentic engagement and self-regulation, with more frequent and specific strategic adjustments between attempts;
- **P3.** Device-based indicators of motor engagement will be positively associated with IMI enjoyment and perceived competence.

Given the guidance hypothesis, no advantage in raw reaction time or accuracy is assumed; differences are expected mainly in how athletes engage with and use information.

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3.2. Design, Participants and Intervention

The study adopts a two-arm, parallel-group feasibility design with repeated measures, reported according to the CONSORT extension for pilot and feasibility trials (Eldridge et al., 2016); the sample is not sized to test efficacy. Forty to 60 adult athletes (recreational or competitive) training at least twice a week, without injuries preventing reactive tasks and without prior systematic use of light-based devices, will be recruited from sports clubs and allocated by a computer-generated sequence stratified by competitive level; group-level allocation may be used for intact training groups to prevent contamination.

The intervention uses BlazePod with 4 to 6 pods. Tasks progress from fixed to random sequences and then to selective responses (e.g., reacting to one colour among distractors); for each trial, the device records stimuli reached, mean reaction time and errors. Similar cognitive-motor progressions have been applied with secondary school students (Cusano & Maddalena, 2025). After one familiarisation and one baseline session, the intervention comprises 4 to 6 sessions over two to three weeks, each with three task blocks (Table 2). Where possible, the same coach delivers both conditions.

Table 2. Structure of each task block by condition.

Phase	Experimental condition	Comparison condition
1. Interactive motor task	30–45 s reactive task	Same task
2. Immediate feedback	Coach shows 1–2 selected indicators (e.g., hits, errors)	Data recorded by the device, no structured presentation
3. Guided reflection	3–4 min prompts: what changed? where did errors occur? what will you do differently?	Equivalent rest time, no prompts
4. Intended adjustment	Athlete states one specific adjustment	—
5. Renewed attempt	Task repeated, adjustment tested	Task repeated

Note. Both conditions use the same devices, tasks and total training time; the dash indicates that the phase is not delivered.

The independent variable is therefore the pedagogical use of information, not the technology itself: the comparison condition is a technology-as-usual condition rather than a no-technology control. To limit dependency on external feedback, the coach shows at most two indicators per block and, in later sessions, asks athletes to estimate their performance before seeing the data. The coach receives brief training and a written guide, and an independent observer completes a fidelity checklist (phases delivered, reflection duration, indicators shown, informational language) in at least one third of sessions.

3.3. Data Collection and Analysis

Data collection combines three sources:

- device-generated indicators (stimuli reached, mean reaction time, errors, within-block variability), with the difference between first and renewed attempts used as an adjustment index;
- the IMI Interest/Enjoyment and Perceived Competence subscales, administered at baseline, mid-intervention and post-intervention;
- reflection records: responses to the prompts in the experimental condition and a short end-of-session note on what athletes would change in the comparison condition.

Reflections will be coded as *recognition*, *diagnosis*, *planning* and *enactment*, following the self-regulation cycle; two coders will independently code a subsample and report agreement. Feasibility outcomes will be reported descriptively with 95% confidence intervals. Exploratory comparisons will use mixed models (condition × time, participant as random effect), reported as effect sizes with confidence intervals; P3 will be examined through correlations, and reflections through category frequencies and thematic analysis (Braun & Clarke, 2006). The protocol will be submitted to the institutional ethics committee; informed consent will be obtained from all participants, and pseudonymised data will not be shared with club staff for selection purposes.

3.4. Feasibility Criteria and Expected Outcomes

Progression to a full trial will depend on the pre-specified criteria in Table 3; values below threshold will indicate which procedures need revision.

Table 3. Pre-specified feasibility criteria.

Criterion	Indicator	Threshold to proceed
Recruitment	Athletes enrolled out of those eligible	At least 40 participants within the recruitment period
Retention	Participants completing post-intervention measures	≥ 80%
Adherence	Sessions attended per participant	≥ 80% of planned sessions
Fidelity	Checklist items delivered as planned	≥ 90% in observed sessions
Time feasibility	Reflection phase within planned duration	3–4 min in ≥ 80% of blocks
Data completeness	Complete device and IMI records	≥ 90%
Coding reliability	Inter-coder agreement on reflection categories	Acceptable agreement before full coding

If feasible, the study will provide variability estimates for sizing a definitive trial, an initial indication of whether the experimental sequence is associated with more planning and enactment of adjustments (P2), and qualitative evidence on how athletes perceive the use of their own data. Given the small sample, these outcomes will serve to refine the intervention, not to establish effectiveness.

4. Discussion

The framework distinguishes three levels that are often conflated: *data* are what the device records; *information* is the subset the coach selects as relevant to the task goal; *feedback* is information the learner interprets and uses to modify a subsequent action. Devices produce data automatically, whereas the transition to information and feedback is a pedagogical act. The coach is therefore not replaced by technology but becomes the mediator between data and learning, which corresponds to the design dimension of teacher feedback literacy (Carless & Winstone, 2023). This extends previous work on the coach's role in integrating technical, tactical, physical and cognitive components within the training session (Cusano, 2019).

Five design principles follow for practitioners:

- **Select.** One or two indicators linked to the task goal are more usable than a full dashboard and reduce dependency;
- **Frame data as task information.** Feedback on task and process, rather than on the person or on rankings, supports learning (Hattie & Timperley, 2007);
- **Close the loop.** Data shown without an opportunity to try again remain a score;
- **Fade external feedback.** Estimating one's own performance before seeing the data builds error detection and self-assessment (Nicol & Macfarlane-Dick, 2006);
- **Share control.** Letting athletes choose when to see data, or which indicator to focus on, supports autonomy (Wulf & Lewthwaite, 2016).

In technology-rich motor settings, engagement is thus not a property of the device but the outcome of a designed relationship between task, data, reflection and action. The framework is intended to be transferable to school physical education, which would require simpler prompts, attention to the social visibility of data among peers and specific ethical procedures for minors.

The study has limitations. The sample does not allow conclusions on effectiveness; delivery of both conditions by the same coach risks contamination, which the fidelity checklist monitors but does not eliminate; the IMI captures only part of emotional engagement, cognitive engagement is inferred from device indicators, and the short duration precludes retention and transfer tests. Future research should address these aspects, develop a validated measure of agentic engagement in sport and compare feedback schedules, such as coach-selected versus athlete-requested feedback.

5. Conclusions

Interactive technologies in sport and physical education can move from tools for measuring reaction time to instruments embedded in a formative feedback cycle. Device-generated data acquire pedagogical value only when they are selected, interpreted and followed by an opportunity to act. Engagement derives not from the

technology itself but from the pedagogical design through which it is used, with the coach as the central mediator between data and learning.

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