

Principles for technology use in athlete support across the skill level continuum

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1 **Principles for technology use in athlete support across the skill level continuum**

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25 **Abstract**

26 A major challenge to sport practitioners working across all levels of sport is ensuring that
27 technological platforms are integrated effectively to assist learning along the development
28 pathway. Under the framework of ecological dynamics, we introduce technology as a *support*
29 *opportunity* for athletes to learn to become better attuned to, and utilise, key sources of
30 information to self-regulate their actions. Importantly, technology not only supports learning,
31 but also serves as a tool to encourage active engagement in learning from early childhood to
32 late adulthood. Coaches also need to be wary of the potential perils of the mismanagement of
33 technology use and how it can act as a *learning rate limiter*. Misuse of technological tools
34 may inhibit the learning process by inhibiting an athlete's ability or willingness to explore
35 and exploit available information in the performance environment, as well as stimulate
36 possible feelings of control and surveillance. By illustrating how technology may
37 complement athlete learning under the guidance of the theoretical framework of ecological
38 dynamics, it is intended that coaches may gain a better understanding of how technological
39 tools can be used more strategically to enhance learning.

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43 **Keywords:** learning, athlete support, performance preparation, coach education, feedback,
44 technology implementation

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51 **Introduction**

52 The continued and rapid integration of technology into modern society provides users with
53 the ability to access information at alarmingly fast rates, which may be a *curse* and a
54 *blessing*. Whilst this availability of information may be useful to advance knowledge and
55 understanding, in sports, it presents challenges to sport practitioners working closely with
56 athletes. Technology is used in many different ways by contemporary sports practitioners to
57 support athlete development and preparation for, and recovery from, competitive
58 performance.¹ In these processes, technology implementation provides *augmented*
59 *information* as guidance and feedback to complement the performance-based sources gained
60 by athletes. Practitioners need to decide how best to interpret, understand and communicate
61 this form of augmented information back to athletes. For example, live video feedback
62 platforms may be used in training settings to guide the attention of athletes to relevant
63 opportunities for action in competitive performance. Alternatively, this same platform may be
64 (mis)used alongside too much prescriptive instructions, potentially detaching the athlete from
65 the surrounding flow of information available for exploitation in the performance
66 environment. Importantly, the trend of the continued insertion of technologies into sports
67 performance environments is super-charged by professional sports organisations driven to
68 find a competitive edge to meet commercial goals and sponsor requirements. A danger for
69 coaches across the skill level continuum is *overuse* or *misuse* of technologies. Here, we argue
70 that practitioners, could avoid this pitfall by invoking key theoretical principles, in a
71 framework like ecological dynamics, for guiding implementation of new technologies to
72 provide augmented information for athlete development and performance preparation.¹

73 The importance of understanding how technology can be integrated in sport training
74 environments, mirrors the challenges for everyday life, as summarised by Dreyfus and

75 Spinosa: ‘How can we relate ourselves to technology in a way that not only resists it’s
76 devastation but also gives it a positive role in our lives?’.^{2(p.159)} The difficulty in finding this
77 ‘sweet spot’ with technology use can be observed through theoretical arguments which
78 highlight the positive learning effects of technology use on skill performance.^{3,4}
79 Simultaneously, these ideas also identify potential issues in (mis)using data for ‘control’ and
80 ‘surveillance’ (termed *dataveillance*) of athletes,^{5,6} preventing them from innovating and
81 exploring autonomous performance solutions.⁷ This limitation is exemplified through
82 reflections of leading professional cycling teams where the need to keep up with technology
83 use seemingly outweighs concerns about overuse to the point where they are ‘in the process
84 of turning riders into robots’, lacking agency when personally navigating demands of a
85 competition environment.⁸ Whilst difficulties in harnessing technology use have previously
86 been discussed in the sport science literature,^{9,10} little research to date has attempted to
87 consider the complementary role of technology in learning, guided by theoretical principles
88 to better understand its implementation. Here, it will be discussed how an ecological
89 dynamics theoretical rationale for athlete development and preparation for performance
90 across skill levels positions technology as an augmented informational constraint, providing
91 evidence to support the way that coaches, practitioners and athletes effectively navigate in
92 competitive performance environments and develop expertise. Practical applications will also
93 be discussed regarding the potential impact on learning, to assist theoretical understanding of
94 how technology implementation could be achieved in sport, exemplifying how they are often
95 actually used in coaching.

96

97 **Learning under an Ecological Dynamics framework**

98 A contemporary conceptualisation of athlete learning and development has been
99 proposed within ecological dynamics, a theoretical framework that integrates ecological

100 psychology and dynamical systems theory.¹¹⁻¹³ In this framework, behaviour emerges under a
101 range of interacting constraints within the athlete-environment system (i.e., various personal,
102 task and environmental features and characteristics that shape behaviour)¹⁴. Within this
103 integrated system, athletes are considered to directly perceive surrounding environmental
104 information (i.e., from spaces, gaps and locations in performance contexts, performance
105 surfaces, events, objects, and other athletes) to guide their actions in practice and
106 competition.¹³ Consequently, learning within an ecological dynamics framework is not
107 derived through the proliferation and elaboration of internalised representations, but is the
108 process of athletes searching for, perceiving and attuning to surrounding information sources
109 that specify relevant environmental properties to support their actions, enhancing function
110 and subsequent action capabilities.¹⁵ The concept of athletes perceiving relevant information
111 sources to regulate actions is based on James Gibson's theory of affordances.¹⁶ Affordances
112 are 'possibilities or opportunities for action' which proliferate in the environment
113 surrounding the individual, inviting interactions.¹⁶ Seeking and using affordances in a
114 performance landscape is a most important feature of skilled behaviour and expertise in sport
115 which technology implementation can support and enrich.^{1, 17} This ecological view of
116 learning in sport has been conceptualised as *wayfinding*, where athletes negotiate different
117 locations of a sporting landscape (i.e., a climber using more complex holds and grips in
118 indoor and outdoor surfaces or a swimmer navigating outdoor waterscapes and indoor pools)
119 with 'purposeful, intentional and self-regulated' movements.^{18(p.2)}

120 Learning under an ecological dynamics framework, therefore, seeks to facilitate the
121 emergence of more adaptive, functional relationships between an athlete and a specific
122 performance environment.¹⁹ According to these ideas, the focus of learning designs in sport
123 practice settings, augmented by technological platforms, should not be on *acting* (rehearsing
124 and repeating a technical action), nor *reacting* to external stimuli. Rather, technology use

125 could be used to encourage athletes to *interact* with information designed into practice
126 environments, searching for, and exploiting, available affordances to facilitate stable, yet
127 adaptable, movement solutions or collective team synergies.^{17, 20}

128

129 **Technology in sport**

130 Insertion of ‘state-of-the-art’ technology into coaching practices is gaining increasing
131 consideration across sports and science.²¹ This trend often appears to be exploited from a
132 commercial perspective, leading to a ‘billion-dollar industry’ behind sports technologies.²²
133 However, it is questionable to what extent sports coaches follow a theory-driven framework in
134 implementing and using such technologies in practice.^{1, 23} This potential lack of understanding
135 leads to a fundamental concern regarding coaches’ approaches towards functionally integrating
136 technology around training session designs and competition.

137 Figure 1 provides a depiction of an ecological perspective on technology use to enhance
138 skill adaptation and learning, with the aim of supporting coaches in better understanding the
139 implementation of various categories of technology into practice. The central section of Figure
140 1 provides a theoretical framework for viewing the roles of practice co-design (i.e., continuous
141 athlete-coach collaborations in designing practice environments) and holistic athlete-
142 environment integration (i.e., considering the mutual and inseparable relationship between
143 individual athletes and their environment). Figure 1 implicates four categories which we will
144 detail in the section on technology implementation under and ecological dynamics framework
145 below. The proposed categories aim to provide an introductory overview and thus, the figure
146 does not claim to be exhaustive.

147

148

[Figure 1 here]

149

150 1) *Technological equipment modification and training machinery.* Innovative training
151 tools and equipment modification may guide athletes' use of perception, increasing perceived
152 task complexity, and driving the exploratory search for functional movement solutions within
153 the practice landscape.²⁴ For example, use of stroboscopic visual devices, eye movement/gaze
154 behaviour registration technology,^{25,26} or technically modified balls, rackets or clubs²⁷ may
155 provide insight into athletes' perceptual attunement to environmental information that is
156 coupled with their adaptations to events in the performance context.²⁸ The assumption is that
157 the orientation of eye movements in the practice landscape captures visual focus and attention.
158 On the other hand, advanced training technologies, such as robotic (football) training machines
159 like the 'Footbonaut'²⁹ or VR-based training systems¹⁷ may allow researchers, coaches and
160 athletes to manipulate various task and environmental constraints and co-design practice
161 contexts, based on data from performance analytics.

162 2) *Physical management/ tracking technology.* Motion tracking technologies aim to
163 collect performance data using (wearable) devices and integrate this information into analysis
164 via computer-based data processing solutions. For example, whilst junior coaches may use
165 'Garmin' sports watches to collect movement data, elite coaches may access data collected
166 from heart rate monitors, global positioning systems or accelerometers which could further be
167 processed and managed on platforms, such as 'SAP Sports One' or 'Kitman Labs'. Often, such
168 devices involve data collection on critical performance metrics including running velocities;
169 distances (at various speeds and intensities); practice volumes; player and force loadings; and
170 frequency of ball contacts and collisions.³⁰

171 3) *Performance analysis technology.* Use of performance analysis technology to
172 support data scientists and performance analysts displays a common trend in high-performance
173 sport.³¹ For example, technology can assist performance analysis through sophisticated video
174 analysis software (e.g., 'Hudl Sportscode' or 'Metrica'), graphic video enhancement

175 programmes (e.g., ‘Coach Paint’ or ‘KilpDraw’) or (*big data*-driven) recruitment and scouting
176 platforms (e.g., ‘Wyscout’ or ‘Statsbomb’). While some performance-driven technology may
177 appear to be rather suitable for sports organisations at the elite level, more accessible software
178 for a wider range of coaches, independent of sport and performance level, is constantly
179 emerging (e.g., ‘Focus X2’ or ‘Nacsport’).

180 4) *Video-based feedback technology*. The use of video technology applied to training
181 sessions for both team and individual sports can play a major part for athlete-coach interactions
182 (e.g., ‘Dartfish’ or ‘Coaches eye’).³² In a recent ecological conceptualisation concerning
183 various coaching intervention methods, Otte and colleagues elaborated on the use of (live)
184 video feedback for tactical analysis, (real-time) self-video feedback and model learning.³³
185 Here, video feedback could be used to guide athletes’ exploratory activities during practice by
186 constraining the perceptual search space and guiding attention towards relevant affordances.
187 Recorded video footage of performance by teams or individuals, often without any further
188 verbal guidance by coaches, may provide augmented feedback for athletes to visualise and
189 adapt (movement) solutions, and to successfully solve goal-oriented problems. In addition to
190 this theoretical framing of coaches’ external feedback and instruction methods, practical
191 implementation of video-based technology and filming equipment, including point-of-view
192 cameras, mobile tablets and drone technology offer exciting avenues for developing *softer* (i.e.,
193 less prescriptive and directing) pedagogies engaging athletes in co-designing relevant practice
194 task constraints.

195

196 **Technology use in an ecological dynamics framework**

197 Technology use involving concepts in ecological dynamics for learning design,
198 highlights the inseparability of athletes and their environments (central section in Figure 1).¹³
199 While traditional views emphasise the top-down ordering and isolation of “movement-

200 regulating sub-systems, such as perception, action, cognition and emotion”,^{31 (p.4)} an ecological
201 view (on technology use) stresses the mutual and reciprocal interactions of these sub-systems
202 under emerging constraints.¹³ Successful performance interactions between technology,
203 athletes and their environment are multidirectional and thus, do not originate internally in the
204 isolated brain.³⁴ Put simply, technology affords coaches an important avenue to provide
205 augmented information, assist athletes’ search processes during practice, and to guide their
206 attention towards functional movement solutions. Under this perspective, technology is viewed
207 as a *support opportunity* for athletes to learn to perceptually attune to, and utilise, relevant
208 affordances and environmental information that sustain self-regulated actions. In this way,
209 information from technological platforms serves as a critical informational constraint
210 influencing athlete performance behaviours. This additional information may be made
211 available to athletes and teams explicitly through data streams of snapshots or implicitly to be
212 detected as invariants in surrounding information for regulating their actions. Technology also
213 provides an opportunity for coaches to co-design representative practice tasks, analyse
214 competition demands to enhance future practice interventions and assess skill effectiveness
215 based on quantifiable data.^{12, 21}

216

217 **Integration of technology can assist learning across the skill level continuum**

218 A major challenge to sport practitioners working across all levels of sport is ensuring
219 that technological platforms are integrated effectively to assist learning along the
220 development pathway (i.e., an athlete’s journey from novice to high performance athlete).
221 Sport practitioners are faced with many barriers and challenges to effectively integrate
222 technology, including: 1) an appreciation of how technology can be used in practice to
223 enhance learning, 2) ensuring that specific technological platforms support the current skill
224 level and needs of the athlete/s, and 3), how a range of sub-discipline specialists in high

225 performance environments collaborate to integrate technology functionally and coherently in
226 practice.³⁵

227 Traditionally, the coach's role in the athlete learning process is conceived as one
228 where high levels of prescriptive instruction and concurrent feedback are provided to
229 learners³⁶ moving them towards an optimal movement template. The one-way process of the
230 coach continuously transmitting knowledge to the passive athlete is outdated and can reduce
231 their responsiveness to critical information sources offered within performance environments.
232 ³⁷ In advocating a move away from such *coach-centred* approaches, Woods and colleagues
233 have argued that a role re-conceptualisation is needed for sport practitioners to one of
234 *learning designer*, where coaches facilitate athlete exploration of performance landscapes.³⁸
235 This idea of athletes self-regulating to *find their way* aligns with the arguments of the
236 prominent ecological psychologist, Edward Reed, who suggested that individuals do not seek
237 to construct internalised knowledge structures (as discussed previously) but seek values
238 (affordances) and meanings (information) when negotiating a performance environment.³⁹

239 A source of information more aligned to wayfinding is transition information. This
240 category of augmented information acts as a control parameter (a key source of information)
241 to guide athletes in a process of searching, discovering, and exploiting affordances situated in
242 performance landscapes. Available opportunities for action can be used to realise task goals.
243 ⁴⁰ For example, at the expert end of the skill continuum, experienced mountain climbers can
244 collaborate using action cameras such as GoPro units, to share route transition information to
245 help each other detect and utilise affordances (i.e., useable grips, finger combinations and
246 holds in the rock structure) to find their way across a surface efficiently and effectively.⁴¹
247 However, the process of a coach or athlete sharing transition information may be a challenge
248 in dynamic sports when the sporting landscape is situated in large and diverse space (e.g., a
249 young child playing on a soccer pitch for the first time or a seasoned cyclist preparing for a

250 multi-stage race). These regulatory information sources may not be perceived without first
251 exploring and navigating through the space to experience interactions with them (even
252 simulated in VR). Here, technology can be a very useful tool in providing transition
253 information to wayfind a path through a challenging context (e.g., cyclists could use Garmin
254 Connect or Strava data of previous routes to identify accelerations in speed, heart rate spikes,
255 or sustained periods of high watt outputs that may indicate race strategies or when to
256 conserve energy). This approach can enculturate athletes into a lifetime habit of learning to
257 search for value and meaning through the process of attuning to transition information
258 available in a performance environment.

259 To effectively integrate technological tools into the coaching process, it is essential
260 that practitioners first identify the current needs of athletes and differentiate between skill
261 development and skill refinement, and consider where athletes are in the search, discover,
262 and exploit stages of learning.⁴² It is important to note here, that an athlete reaching a certain
263 stage of learning does not automatically imply that technology should be integrated within
264 their training sessions. Rather, and as promoted by the ecological dynamics framework,
265 coaches need to understand the implications of using this form of augmented informational
266 constraint from an individual-environment level of analysis. Less experienced coaches
267 working with less skilful athletes are encouraged to focus on carefully implementing
268 technology with the aim of helping athletes to co-design opportunities for utilising
269 affordances and performance enrichment, based on augmented information provided by
270 performance feedback systems. To exemplify, a coach working with junior middle distance
271 track athletes who have spent much of their practice history focusing on developing physical
272 capacities, may be unresponsive to challenges for identifying *attacking* opportunities
273 (affordances) or situations they may have to *respond to* during competition and could
274 therefore, lack race intelligence.⁴³ This emergent problem could be addressed through an

275 integrated approach whereby: 1) video feedback for tactical race analysis can be used to
276 identify transition information to attune the athlete's attention to affordances for attacking in
277 a race, 2) the coach and athlete can then co-design practice race simulations based on these
278 key affordances, and 3), depending on the agreed physiological response, manipulate load
279 demands based on lap times and heart rate data. Approaching technological use through the
280 co-design concept early in an athlete's development can provide useful opportunities for self-
281 regulation during performance and development. Technologies can invoke the positive
282 connections of athletes with coaches, and lead to feelings of competence when mastering new
283 skills.

284

285 **How technology can interfere with learning**

286 A common thread through the discussion thus far has been how technology use by
287 coaches can help facilitate key search processes and act as a *support opportunity* for athletes
288 when viewed through an ecological dynamics lens. It is important, however, to recognise
289 how technology, in providing augmented information, can *interfere* with learning if used
290 incorrectly or mismanaged. In this section, we draw attention to the misuse of technology and
291 how it can act as a *learning rate limiter* rather than a *support opportunity*. Two specific
292 potential issues will be explored: (1) Impact of explicit instructions, and (2) Issues of control
293 and surveillance.

294 (1) Impact of explicit instructions

295 According to James Gibson ¹⁶ *knowledge about* the performance environment is related to
296 verbal descriptions often accompanied by exposure to images, abstract depictions, pictures
297 and/or video analysis. ²³ It can be a powerful platform for shared knowledge that coaches can
298 use to direct an athlete's attention to certain features of an opponent's play or team defensive
299 structures, for example. Questions arise over the nature of the responses elicited from athletes

300 in sharing this knowledge, especially when verbal responses from athletes (telling) are
301 preferred over interactions with a practice environment (doing).⁴⁴ Issues can surface,
302 however, when coaches supplement video feedback, for instance, with the explicit
303 prescription of specific movement solutions rather than encouraging exploration of learning
304 strategies.⁴ In this respect, context is everything for coordinating such interactions. For
305 example, a coach may use video feedback with a junior long jump athlete during training, but
306 supplement its use with explicit instructions on key technical positions with no regard to
307 jump distance or the key variables of performance contexts that athletes need to navigate
308 within competitive performance.^{43,45} In contrast, professional cyclists can have *knowledge of*
309 ¹⁶ the environment relayed to them via earpieces in real-time or via computer screens on their
310 handlebars during both training and races (i.e., positions of rivals in the peloton, power
311 output). This information is often used to highlight how to coordinate interactions with a
312 performance environment, through augmented information on specific points of attacks or to
313 optimise physiological training loads during training. Importantly, both examples here may
314 reduce an athlete's ability or willingness to explore and exploit available information in the
315 performance environment when trying to *find their way*. Coaches need to be attuned to when
316 it is appropriate to incorporate technology into the learning journey of athletes and recognise
317 that sports performance is more than just (re)producing a technical performance.⁴³ It is
318 important to ensure that technological tools are accompanied by appropriate verbal guidance
319 that encourages and supports athlete wayfinding. For example, instead of providing ball by
320 ball analysis to a mid-handicap golfer using sophisticated ball tracking devices such as
321 Trackman, the coach may use an initial swing analysis alongside carefully targeted
322 questioning and guidance that supports the athlete's learning and encourages exploration. If
323 the focus of the session is on controlling ball flight, then example questions/verbal guidance
324 to frame interactions during practice may include: Can you hit this 7-iron at a low trajectory

325 into the target? How did that feel off the club face? Do you think moving the ball
326 back/forward in your stance will impact trajectory? Can you now hit the ball as high as you
327 can using the same club?

328

329 (2) Issues of control and surveillance

330 The constant integration of technology into the coaching process can elicit feelings of athlete
331 lack of control by *dataveillance*, if mismanaged.^{5, 6, 46} For example, use of wearable GPS
332 technologies during training and competition to monitor athlete load during sports such as
333 rugby league or American football may be creating environments where athletes are
334 consciously ‘completing the work to hit imposed performance goals’. Furthermore, feelings
335 of mistrust amongst teammates may also develop. For example, use of instrumented gates in
336 the sport of rowing, where publicly available metrics such as force data and stroke length can
337 be produced in real-time for every stroke and for every athlete in a boat, may lead to team
338 disharmony and mistrust. In observing a reduction in force production by a fellow team
339 member, an athlete may question their team member’s position in the team. Constant feelings
340 of surveillance through technological use can, therefore, serve to ‘dehumanise the athlete
341 experience’,^{47 (p.321)} reducing the athlete to just a ‘number’ (likened to a *chess piece* or *robot*
342 manipulated by an external agent), contributing to orchestrated performance. Notably, this
343 notion of extensive control may be extended by the danger of athletes becoming (too)
344 dependent on software, devices and related coaching feedback. Whilst coaches traditionally
345 may feel the need to overly control and guide athlete learning, encouraging athletes to
346 become better attuned to their own feedback systems to support their own self-regulation
347 when wayfinding is critical. Hence, technology should be used carefully: only as an
348 augmented informational source for learning and development.

349

350 **Summary**

351 Continued growth in the sports technology industry poses interesting challenges for coaches
352 and practitioners charged with preparing athletes for the dynamic nature of sports
353 competition. A thorough understanding of how best to harness these technologies is
354 important to enhance the continued development and improvement of athletes. A theoretical
355 framework, such as ecological dynamics, could provide principles for technology
356 implementation in coaching across the skill level continuum. Under this framework, we
357 introduced technology as a *support opportunity* for athletes to learn to become better attuned
358 to and utilise key sources of available information in the performance environment, which
359 they may use to self-regulate their interactions. Importantly, for the effective integration of
360 technology tools, understanding the current needs of athletes and where they are in the
361 search, discover and exploitative stages of learning is essential. This is a key facet of
362 understanding the coach as a learning facilitator, moving away from the ‘one-size fits all’
363 approach commonly used in traditional coaching methods. If technology is used in this
364 manner, it not only supports learning, but it also serves as a tool to encourage active
365 engagement of athletes in learning from early childhood to late adulthood. Coaches also need
366 to be wary of the potential perils of technology mismanagement and how it can act as a
367 *learning rate limiter*. Potential negative associations with continued observations of
368 augmented information and constant feelings of control and surveillance (during and away
369 from performance) may develop with misuse of technological tools inhibiting self-regulation.
370 By using technology to complement learning, ecological dynamics provides coaches with
371 better understanding of how such tools can be used more strategically to enhance athlete
372 preparation and development. A future challenge for coach education developers is to
373 consider the integration of technology alongside learning frameworks within coach education
374 curricula. In modern life, where athletes are constantly exposed to technology use, it is

375 important that sport organisations avoid turning athletes into ‘docile and compliant robots’,
376 categorising them as a mere commodity in the drive for organisational success.

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497 **Figure Captions**

498 *Figure 1. Overview model of technology use in coaching including key pedagogical principles*
499 *under the framework of ecological dynamics and four proposed technology categories.*
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