

**How can video feedback be used in physical education to support novice learning in gymnastics? Effects on motor learning, self-assessment and motivation**

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1 **How can video feedback be used in Physical Education to support novice learning in**  
 2 **Gymnastics?: Effects on motor learning, self-assessment and motivation.**

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## 14 **Abstract**

15 **Background.** Much of the existing research concerning the use of video feedback (VFB) to  
16 enhance motor learning has been undertaken under strictly controlled experimental  
17 conditions. Few studies have sought to explore the impact of VFB on the skill learning  
18 experience of the students in a structured, school-based Physical Education (PE) setting. Most  
19 of those studies have only used qualitative approaches to implicate the potential value of VFB  
20 to enhance skill acquisition, students' engagement or self-assessment ability. Using a  
21 quantitative approach, the aim of this study was to investigate effects of using VFB on motor  
22 skill acquisition, self-assessment ability and motivation in a school-based learning  
23 environment (structured PE programme) with novice children learning a gymnastic skill.

24 **Method.** Two French classes of beginners took part in a typical five-week learning  
25 programme in gymnastics. During each of the five, weekly lessons participants carried out the  
26 same warm-up routine and exercises. The experimental group (10 girls - 8 boys,  $12.4 \pm 0.5$   
27 years) received VFB intermittently when learning a front handstand to flat back landing.  
28 Video feedback was given after every five attempts, combined with self-assessment and  
29 verbal instructions from the teacher. The control group (12 girls - 13 boys,  $12.6 \pm 0.4$  years)  
30 received exactly the same training, but was not given VFB. In order to assess progress in  
31 motor skills, the arm-trunk angle (hand-shoulder-hip) was measured in the sagittal plane just  
32 as the hips formed a vertical line with the shoulders. Motivation was assessed using the  
33 Situational Motivation Scale questionnaire (Guay, Vallerand, and Blanchard 2000), and self-  
34 assessment ability was measured by self-perception task scores.

35  
36 **Results.** Statistical analysis of arm-trunk angle values showed significant differences only for  
37 the VFB group between the 5th lesson and all other lessons. Between lessons 4 and 5, the  
38 arm-trunk angle value increased significantly from  $146.6 \pm 16.9$  degrees to  $161.2 \pm 14.2$

39 degrees ( $p < 0.001$ ;  $ES = 0.94$ ). Self-assessment scores improved significantly for the VFB  
40 group between lesson 1 and lesson 2 ( $p < 0.01$ ,  $ES = 1.79$ ), and between lesson 4 to lesson 5  
41 ( $p < 0.01$ ,  $ES = 0.94$ ). Amotivation decreased significantly for the VFB group between lesson  
42 1 and lesson 5 ( $3.06 \pm 1.42$  vs  $2.12 \pm 0.62$ ,  $p < 0.001$ ,  $ES = -0.89$ ).

43  
44 **Discussion/conclusion.** Our quantitative data, identifying key movement changes as a  
45 function of experience in a structured PE programme, were congruent with outcomes of  
46 previous qualitative research supporting the role of VFB. This study highlights the potential  
47 relevance of using VFB in fostering motor learning, motivation and self-assessment during a  
48 physical education programme with young children. Future pedagogical research is needed to  
49 examine the ways students could use VFB technology for greater self-regulation, with the  
50 potential to deliver appropriate movement feedback, based on different levels of experience in  
51 students.

52  
53 **Keywords:** feedback, pedagogy, video-based technology, learning, self-regulation.

54

55

56

## 57 **Introduction**

58 Feedback is inextricably linked to processes of learning and teaching (Bangert-Drowns et al.  
59 1991) and its use during the teaching process has been the focus of many studies (Georges  
60 and Pansu 2011). The research specificity of feedback in Physical Education (PE) lies in its  
61 ensuing effect on learning and performance of motor skills. Feedback may be defined as the  
62 return of performance information occurring within a behavioural regulation loop, where error  
63 detection and correction are essential to motor learning (Mulder and Hulstijn 1985; Schmidt  
64 and Lee 2005). Literature investigating feedback has become extremely rich since the  
65 establishment of the cybernetic approach to learning (Wiener 1948). Subsequently, a large  
66 amount of empirical research in the field of motor learning has emerged over 50 years,  
67 providing rich insights on the role of feedback on performance, learning and behaviour  
68 change (e.g., Bilodeau and Bilodeau 1961; Bilodeau 1969; Brunelle 1980, Brunelle and  
69 Carufel 1982, Brunelle et al. 1983; De Knop 1983; Piéron and Piron 1981).

70 Various types of feedback have been identified in pedagogical research in PE setting,  
71 such as augmented feedback (Fishman and Tobey 1978), information feedback (Newell and  
72 Valvano 1998), congruent feedback (Rink 2003), aligned developmental feedback (Cohen,  
73 Goodway, and Lidor 2012) or interrogative feedback (Driouch et al. 1993; Swalus, Carlier,  
74 and Renard 1991). Research in motor learning and sport pedagogy reports that feedback has  
75 been found to enhance the acquisition of fine and gross motor skills (see Schmidt and  
76 Wrisberg 2008; Wrisberg 2007; Young and Schmidt 1992) and indicated that it is one of the  
77 most powerful instructional variables affecting skill learning.

78 More recently, technological progress has led sports pedagogists and physical  
79 educators to reexamine strategies for providing movement-related feedback and experiment  
80 with new learning aids based more particularly on use of VFB (Rucci and Tomparowski  
81 2010). Video feedback can be defined as the playback to a learner of his/her own (static and  
82 dynamic) image in action. It is an extrinsic or augmented source of feedback (Schmidt and

83 Lee 2005), since it involves additional information related to one's own actions that is not  
84 available without the use of an external aid. It differs from 'intrinsic' feedback, which  
85 represents information that is detectable without external aids. Video feedback can be used to  
86 guide the actions of learners who find it difficult to interpret intrinsic feedback or who have  
87 less stable movement patterns (Swinnen 1996; Hodges, Chua, and Francks 2003).

88         The role of VFB in motor learning has been investigated by two different theoretical  
89 frameworks over the last two decades. According to Swinnen (1996), in one approach the role  
90 of augmented feedback has been undertaken in investigations of movement parametrization  
91 involving specific timing or force requirements. Concepts of information processing theory  
92 have been used to explain its role in a regulation loop to calibrate or reinforce the use of a  
93 general motor program (Schmidt 1975). Since the conceptualisation of Newell (1991) and  
94 Handford et al. (1997), in an ecological dynamics approach to skill acquisition, an increased  
95 interest in the learning of segmental coordination has been developed to understand the role of  
96 augmented feedback. According to Al-Abood, Davids, and Bennett (2001), the ecological  
97 approach considers VFB as a type of instructional constraint which guides a learner during  
98 the search for functional task solutions in specified areas of a perceptual work motor space. **In**  
99 **this theoretical framework, a constraint is considered as a key task variable which can be**  
100 **manipulated in learning design to help the learner in his/her exploration of innovative**  
101 **movement solutions.** More recently, the non linear pedagogy approach has suggested the  
102 need to consider feedback, not to prescribe movement solutions, but to encourage exploration  
103 of learning strategies to exploit natural self organisation processes that emerge during  
104 practice (Renshaw et al. 2010; Chow et al. 2016). In the theoretical framework of ecological  
105 dynamics, VFB is considered as an essential strategy for facilitating the acquisition of new  
106 motor skills by facilitating learners' adaptations during practice.

107         In this respect, numerous studies have demonstrated the effectiveness of VFB in the  
108 acquisition of various sports skills over relatively short learning periods, such as the golf

109 swing (Guadagnoli, Holcomb, and Davis 2002), flip turns in swimming (Hazen et al. 1990),  
110 gymnastics (Merian and Baumberger 2007; Winfrey and Weeks 1993), soccer skills (Ziegler  
111 1994), high jump (Mérián and Baumberger, 2007), diving (Thow, Naemi, and Sanders 2012),  
112 hang power clean in weightlifting (Rucci and Tomparowski 2010), spike jump in volleyball  
113 (Parsons and Alexander 2012) and hurdling (Palao et al. 2013). While results have  
114 highlighted the effectiveness of providing VFB on motor learning, the way it was used in  
115 studies varied depending on learning contexts. Since the study of Kernodle and Carlton  
116 (1992), results from research have shown that a combination of VFB, attentional information  
117 (focusing on a specific point of the movement) and verbal instructions represents a most  
118 functional pedagogical strategy for optimizing search activities during learning (Janelle et al.  
119 1997; Rucci and Tomporowski 2010).

120         However, in the extant literature, important questions remain on the amount of  
121 feedback required for optimizing learning. While increasing the quantity of feedback  
122 promotes learning (Wulf, Schmidt, and Deubel 1993), going beyond a certain limit leads to  
123 the opposite effect (Wulf, Lee, and Schmidt 1994). Relative reduced-frequency feedback  
124 (delivery of feedback after every two or more attempts) is as effective for learning as total  
125 frequency (Lee, White, and Carnahan 1990; Sparrow and Summers 1992; Winstein and  
126 Schmidt 1990). According to Wulf and Shea (2004), total frequency feedback can create  
127 dependence on extrinsic feedback in the long term by inhibiting the development of a  
128 learner's capacity to interpret intrinsic informations. Wulf and Shea (2004) showed that  
129 relative frequency of feedback every five attempts was more effective than total frequency  
130 feedback.

131         How can physical education specialists make sense of this laboratory-based research  
132 to enhance their everyday practice? Providing PE teachers with an increased number of digital  
133 tablets has led them to create learning aids based on presentation VFB (Gubacs-Collins and  
134 Juniu 2009; Kretschmann 2015). Nevertheless, studies seeking to measure the impact of these

135 aids in real-life PE teaching programs are rare in comparison with sport settings (Palao et al.  
136 2013; Ste-Marie et al 2012). Reasons for this void in the literature may include the **lowest**  
137 number of students in sport training groups, or that athletes and coaches theoretically have  
138 greater levels of investment in specific skill improvements (Guadagnoli, Holcomb, and Davis  
139 2002; Smith and Loschner 2002); whereas PE teachers may emphasize different aims such as  
140 motor, cognitive, social, moral, spiritual or cultural development (Sallis and Mc Kenzie  
141 1991). Additional disincentives for PE teachers to assess the efficacy of VFB may relate to  
142 time consuming pressures or economic issues (Norris, Soloway, and Sullivan 2002; Weir and  
143 Connor 2009).

144         Yet, several studies have shown the potential of using VFB in PE teaching to improve  
145 the effectiveness of demonstrations (Lhuisset and Margnes 2014) for enhancing skill learning,  
146 knowledge, and game understanding (Blomqvist, Luthanen, and Laakso 2001). Studies  
147 seeking to assess the specific effect of VFB on motor skill acquisition **in a PE setting at**  
148 **different education levels** have shown its effectiveness when it was coupled with teacher  
149 feedback (Amara et al. 2015; Kretschman 2017; Mérian and Baumberger 2007; Potdevin et  
150 al. 2013; Uhl and Dillon 2009). No effects have been observed when VFB was provided  
151 without instruction as well (Madou and Cottyn 2015).

152         To our knowledge, the few studies, which have sought to explore the impact of VFB  
153 on the learning experiences in PE setting have examined perceptions of learning using  
154 qualitative approaches (Palao et al. 2013). Kretschmann (2017) used a semi-structured  
155 interview methodology with students of 10 years of age, suggesting that they found VFB  
156 helpful for the learning process in swimming. With the same methodology, O'Loughlin,  
157 Chroinin, and O'Grady (2015) showed that VFB positively influenced self-reported  
158 motivation, self-assessment, and engagement when learning basketball skills in students aged  
159 9-10 years. Also, Casey and Jones (2011) showed the effectiveness of using VFB in  
160 enhancing engagement with disaffected year seven students who developed greater depth of



161 knowledge about throwing and catching skills. Others studies have confirmed a positive effect  
162 of VFB on motivation during PE learning (Potdevin et al. 2013; Weir and Connor 2009;  
163 Backaberg, 2016). According to Deci and Ryan's Self-Determination Theory (SDT, 1985,  
164 1991), information provided by VFB enhances perceived control of actions to be  
165 implemented and positively influences intrinsic motivation, which is vital for successful  
166 learning (Horn, 1987, 1992). Self-assessment tasks have been identified as a key pedagogy to  
167 enhance student achievement and motivation (Cauley and McMillan 2010; Hallam et al.  
168 2004) by supporting learners' regulation of their own learning. To our knowledge, no study  
169 has explored the multiple effects of VFB on skill acquisition, self-assesment competencies,  
170 and motivation using quantitative data under the task constraints of a structured, school-based  
171 PE program.

172         The aim of this study was, therefore, to assess the effects of a methodology combining  
173 VFB, attentional information and verbal instructional constraints on the learning of a  
174 gymnastics skill, motivation during learning and student self-assessment ability. The  
175 assessment took place in lessons undertaken during an actual school PE program under  
176 typical teaching conditions. We sought to examine whether the use of VFB would impact  
177 positively on motor learning, self-assessment, and motivation in children during learning in  
178 physical education lessons.

179

## 180 **Methods**

### 181 *Participants*

182         Two classes of Year 7 pupils from the same French secondary school took part in the  
183 study during their gymnastics physical education lessons. The two classes of students were  
184 considered by their teachers to be autonomous and motivated during PE lessons. Video  
185 Feedback was offered to one class who acted as the experimental group, composed of 18  
186 pupils (10 girls and eight boys, age =  $12.4 \pm 0.5$  years old). The other class (control group)

187 included 25 pupils (12 girls and 13 boys, age =  $12.6 \pm 0.4$  years old). During the  
188 investigation, two pupils from each group were not present for one lesson. Informed consent  
189 was obtained from the students and the family of each participant concerning the nature of the  
190 research and the use of video images during lessons for the purposes of studying effects on  
191 learning. The Ethics Committee of the French Ministry of Education approved the research  
192 project on the condition that the study did not disrupt teaching or timetabling within the  
193 school day.

#### 194 *Protocol*

195 Both classes followed the same lessons plan over a period of five weeks at the rate of  
196 one two-hour lesson per week. This sequence represented the normal exposure to physical  
197 education classes in the school timetable for participants. During each of the five lessons,  
198 participants carried out the same warm-up routine and exercises. They then performed an  
199 identical number of attempts per exercise (15 attempts per exercise) to ensure a similar  
200 frequency of practicing the specific actions. Pupils were divided into groups of four to five for  
201 each exercise, and each group took turns to perform all of the suggested exercises. Five  
202 different working zones were organized around the center of the gymnasium, so that the  
203 teacher was able to supervise activity in each of them, when standing near the VFB zone.  
204 After the pupils had completed their 15 trials, they were required to sit and wait for a signal to  
205 go to the next working zone. Written instructions informed the pupils about the study and  
206 about that task they were required to perform in each zone. The pupils also had to put a mark  
207 on a board after each trial and assess their performance according to the task instructions. The  
208 lesson was organized so that each pupil had the time and opportunity to perform every  
209 exercise. At the same time, the methodology allowed the teacher to pay more attention to the  
210 five students in the VFB zone.

211 The front handstand flat back exercise was part of each lesson and represented the  
212 only exercise where the participant's body was turned upside down. All students had no

213 scholar or gymnastics club previous experience of activities that involved placing the body  
214 into a vertically aligned position. The aim of this exercise was for pupils to vertically align  
215 their bodies in an inverted vertical position (arms-trunk-legs), before letting themselves fall  
216 onto their back, keeping their bodies aligned until they hit the mat. During each lesson, pupils  
217 in both groups attempted the exercise 15 times. In other words each participant experienced  
218 75 attempts over the five-week period.

219 Pupils in the experimental group were provided with VFB for this specific exercise  
220 (Figure 1) during all five lessons. An intermittent feedback frequency schedule was  
221 implemented by the teacher (feedback provided after every five trials, rather than after every  
222 trial to allow participants to use intrinsic feedback for the first four trials). Feedback provision  
223 was as follows: at the end of the 5<sup>th</sup> attempt, each pupil was asked to answer the following  
224 question 'Do you think you were in a straight line during this attempt?' He/she was given 20  
225 seconds to answer the question after being moved away from the group. The pupil then  
226 received VFB on his/her performance while watching it on a computer screen. The teacher  
227 froze the image just as the hips projected a vertical line with the shoulder and captured the  
228 angle (arms-trunk) as the pelvis was vertically aligned with the shoulders. The teacher then  
229 discussed the pupil's response with him/her, before providing technical advice on how to  
230 achieve the task goal. Following the feedback session, the pupil made four more attempts  
231 without VFB, then received VFB for the second time after the 10<sup>th</sup> attempt. This time, he/she  
232 was asked an additional question: 'Was your attempt better than the last time you watched it?'  
233 This procedure was repeated up to the 15<sup>th</sup> attempt, when the pupil received VFB for the third  
234 time and had to answer the two questions. The control group followed the same protocol, but  
235 only the teacher had access to the video and did not show it to the pupils. The teacher  
236 provided only verbal feedback to the participants during learning experiences.

237 \*\*\*\*Figure 1 near here\*\*\*\*

238 ***Material***

239 A tripod-mounted video camera (Sportcam/webcam DV 16) was connected to a laptop  
240 (Packard Bell) using a USB cable, and transmitted live images to the screen. The video  
241 analysis software Kinovea was used to freeze frames, and to visually capture and measure the  
242 arm-trunk angle of each participant in the experimental group when performing the required  
243 action. The video camera was placed 3 m from the area on the floor where the student would  
244 lay place his/her hands when performing the action. The camera captured sagittal views of the  
245 participants, who were required to put their hand in a 50 cm x 70 cm marked surface on the  
246 floor to limit parallax effects of image observers.

#### 247 *Data collection*

248 In order to assess progress in motor skills, the arm-trunk angle (hand-shoulder-hip)  
249 was digitally video-recorded and measured in the sagittal plane just as the hips formed a  
250 vertical line with the shoulders during the 5<sup>th</sup>, 10<sup>th</sup> and 15<sup>th</sup> attempt for the pupils in both  
251 groups. In previous work, Potdevin et al. (2013) successfully used this angle value in order to  
252 assess motor learning in this specific task for beginner pupils aged 12 years. Unobtrusive  
253 markers at the wrist, shoulder and hip were fixed on the participant. The camera was  
254 positioned to film the participant in a sagittal plane. The arm-trunk angle was defined by these  
255 three markers and measured by two experimenters. The mean of these three attempts was  
256 calculated for each participant in each lesson.

257 Motivation was assessed using the Situational Motivation Scale questionnaire (SIMS;  
258 Guay, Vallerand, and Blanchard 2000) during lessons 1 and 5 for both groups. This  
259 instrument identifies the three dimensions of motivation: intrinsic, extrinsic (identified and  
260 external) and amotivation.

261 Self-assessment ability corresponds here to the ability to perceive one's body in  
262 action. It is measured by the ability to judge one's own performance and progress. As already  
263 mentioned, this self-evaluation process required pupils to answer a question in each lesson  
264 after the 5<sup>th</sup> attempt: 'Do you think you were in a straight line during this attempt?' as well as

265 an additional question after the 10<sup>th</sup> and 15<sup>th</sup> attempts: 'Was your attempt better than the last  
266 time you watched it?' Finally, participants' self-assessment ability was evaluated via the five  
267 answers given each lesson, where each correct answer was awarded a point (resulting in a  
268 score out of five points).

### 269 *Statistical analysis*

270 Inter rater reliability between the two experimenters for the measurement of 'arm-  
271 trunk angle' was tested using the intraclass correlation coefficient (ICC) according to the  
272 recommendations of Schrouf and Fleiss (1979).

273 Mean and standard deviation values were calculated for each lesson and for each  
274 group for the 'arm-trunk angle' and 'self-assessment ability' variables; and at the first and the  
275 fifth lesson for each group for the different psychometric scores (intrinsic motivation,  
276 identified regulation, external regulation, and amotivation). When normal Gaussian  
277 distribution and sphericity of the data were verified by Shapiro-Wilk's and Mauchly tests, a  
278 two-way ANOVA (group X time) and a Bonferroni post hoc test were used. Otherwise, the  
279 Scheirer Ray Hare test (group X time) and a Wilcoxon post hoc test with Bonferroni  
280 corrections were used.

281 All statistical procedures were performed using the STATISTICA software. For all  
282 post hoc significant differences, effect size (ES) was measured according to Cohen's scale  
283 (1992): absolute effect size values of < 0.2 represent small treatment differences,  
284 approximately 0.5 values represent moderate treatment differences, and > 0.8 represent large  
285 treatment differences The statistical significance levels were fixed at  $p < .05$ ,  $p < .01$  and  $p <$   
286  $.001$ ).

287

### 288 **Results**

289 Significant improvement in motor skill performance from the fifth lesson onwards and  
290 enhanced self-assessment ability from the second lesson **was observed in the experimental**

291 **group. Similarly, a** drop in amotivation scores between the first and the fifth lesson was  
292 revealed in the experimental group only.

### 293 *Arm-trunk angle progression*

294 The intra class correlation coefficient value between measurements of the two experimenters  
295 was 0.98 and mean differences were  $2.9 \pm 2.7$  degree. Arm-trunk angle progression for each  
296 pupil can be seen in Figure 2. Statistical analysis showed significant interaction effects (group  
297 X time;  $F(4, 148) = 3.45$ ;  $p < 0.05$ ) for the arm-trunk angle. Significant differences were  
298 shown for the experimental group between the 5<sup>th</sup> lesson and all other lessons. Between  
299 lessons 4 and 5, the arm-trunk angle increased significantly from  $146.6 \pm 16.9$  degrees to  
300  $161.2 \pm 14.2$  degrees ( $p < 0.001$ ;  $ES = 0.94$ ).

301

302 \*\*\*\*Figure 2 near here\*\*\*\*

303

### 304 *Self-assessment ability*

305 Changes in vertical alignment self-assessment scores can be seen in Figure 3. Statistical  
306 analysis revealed significant group-time interaction effects ( $H(4, 148) = 173.19$ ,  $p < 0.001$ ).  
307 Post hoc analysis showed significant paired differences for the experimental group only, with  
308 self-assessment scores being significantly higher for lesson 5 than for lesson 4 ( $p < 0.01$ ,  $ES =$   
309  $0.94$ ) and lesson 1 ( $p < 0.001$ ,  $ES = 2.51$ ), and between lesson 1 and lesson 2 ( $p < 0.01$ ,  $ES =$   
310  $1.79$ ).

311 \*\*\*\*Figure 3 near here\*\*\*\*

312

### 313 *Changes in motivation scores*

314 Motivation scores are presented in Table 1. Results showed significant interaction effects  
315 (group X time) for intrinsic motivation ( $H(1, 40) = 69.4$ ;  $p < 0.01$ ) and for amotivation ( $F(1,$

316 40) = 12.55,  $p < 0.001$ ). Amotivation decreased significantly for the VFB group between  
317 lesson 1 and lesson 5 ( $3.06 \pm 1.42$  vs  $2.12 \pm 0.62$ ,  $p < 0.001$ ,  $ES = -0.89$ ).

318

319 \*\*\*\*\*Table 1 near here\*\*\*\*\*

320

## 321 **Discussion**

322 The aim of this study was to assess the effects of a VFB based learning aid implemented in a  
323 series of five lessons in a physical education program to evaluate effects on [the learning](#)  
324 [experiences](#). [In that way, we evaluated](#) the learning of the gymnastics skill, motivation during  
325 learning and self-assessment ability in real-life teaching conditions, rather than an  
326 experimental laboratory.

### 327 *Significant development of motor skills and self-assessment ability*

328 Results showed significant progress in motor skills between the first and fifth lessons  
329 for the experimental group. [Arm-trunk angle values in the first lesson were consistent with](#)  
330 [data reported by Potdevin et al. \(2013\), confirming the novice level of the participants](#). No  
331 significant changes were observed in the arm-trunk angle between lesson 1 and 4. But there  
332 was a substantial increase in this angle between lessons 4 and 5 ( $ES = 0.94$ ), suggesting [the](#)  
333 [nonlinearity of the transitions in the learning process between lessons](#). This result is consistent  
334 with numerous studies highlighting the non-linear nature of motor skills progression during  
335 learning, with periods of stability and sudden transitions emerging throughout (Delignières,  
336 Teulier, and Nourrit 2009; Nourrit et al. 2003; Teulier and Delignières, 2007). The evidence  
337 suggests that VFB acted as a key augmented informational constraint to drive the transition in  
338 motor learning. As for the control group, the arm-trunk angle values did not show any  
339 significant changes, and these results reinforce the role of VFB in optimizing motor learning  
340 (compared to traditional use of verbal instructions only) over a short period in a formal  
341 physical education program.

342           The progress observed in the experimental group in a school physical education lesson  
343 context is consistent with the findings of several experimental studies using a combination of  
344 VFB and verbal instructions for the rapid acquisition of complex skills (Boutmans 1992;  
345 Boyce et al. 1996; Erbaugh 1985; Guadagnoli, Holcomb, and Davis 2002; Janelle et al. 1997;  
346 Kernodle and Carlton 1992; Mérian and Baumberger 2007; Potdevin et al. 2013).  
347 Nevertheless, the results appear to be at odds with those of Rothstein and Arnold (1976), and  
348 Salmoni, Schmidt, and Walter (1984), which pointed to the need for learners to have reached  
349 a certain level of competency before VFB could be effective in optimizing their learning.  
350 While the initial level of participants in this study was low, they progressed quickly (in 75  
351 attempts), thus demonstrating that VFB could act as a powerful augmented informational  
352 constraint, which **shortens the** motor learning **process** in a **PE** context. Unlike Guadagnoli,  
353 Holcomb, and Davis (2002), and Rothstein and Arnold (1976), the results here likewise  
354 showed that learners need not train for a long time with VFB for the latter to contribute to  
355 motor learning, even in the case of young children as learners.

356           The rapid improvement in the self-assessment ability which occurred at lesson 2 (ES =  
357 1.79) showed that pupils in the experimental group were quick to associate available intrinsic  
358 feedback linked to proprioception as they turned upside down with extrinsic information  
359 related to VFB. These results appeared to be consistent with studies by Winfrey and Week  
360 (1993), which demonstrated that female gymnasts aged between 8 and 13 developed self-  
361 grading abilities on the beam when they were given VFB. Under the task constraints of  
362 elementary school PE teaching, Hamlin (2005) showed that VFB could help students to  
363 analyze their own performances if criteria were provided to help student to structure their  
364 evaluations with concrete expectations (McMillan and Hearn 2008). Our study with VFB was  
365 associated with an attentional focus on the quantified arm-trunk angle was aligned with these  
366 principles. Finally, our findings, based on self-assessment scores, were congruent with  
367 previous qualitative research supporting the role of VFB in the self-assessment process



368 (Kretchmann 2017; O'Loughlin, Chroinin, and O'Grady 2015).

369           A new insight from our study indicates the **rapidity** of performance progress when  
370 using the self-assessment task in the experimental group. This ability to rapidly exploit the  
371 VFB-based learning aid may be explained due to several reasons. The first lies in the use of  
372 VFB in an intermittent scheduling on a 20% basis. This 'one in five attempts' scheduling  
373 avoided dependence and provided opportunities for pupils to also exploit intrinsic information  
374 (Wulf and Shea 2004), from valuable sources such as proprioception when turning upside  
375 down (Schmidt, Lange, and Young 1990). It also allowed them to continue their learning in  
376 an autonomous way, even when VFB was not provided (in this case, for four out of five  
377 attempts). Conducting the self-assessment task every five attempts most likely generated an  
378 attentional focus on perceived sensations when turning upside down in order to answer, as  
379 accurately as possible, the question 'Do you think your attempt was better than the last time  
380 you watched it?' Furthermore, this type of feedback, using freeze-frames and measuring the  
381 arm-trunk angle, is one that beginner-level pupils appear to be able to exploit. Simplifying  
382 feedback in this way appeared to contribute to reducing reliance on conscious cognitive  
383 control of the movement when identifying the important information in VFB and to  
384 enhancing its impact on learning and perception of the body in action (Hegarty, Kriz, and  
385 Cate 2003; Mayer et al. 2005). Further, requesting the pupil's self-assessment immediately  
386 prior to VFB was good practice because it is likely to increase the pupil's attention capacity  
387 for watching the video and listening to the teacher's technical instructions and advice.

388           A gap between self-assessment related progress (Lesson 2) and that of motor skills  
389 enhancement (Lesson 5) should be noted for the experimental group. This result appears to be  
390 consistent with the various theories on learning stages, which differentiate the cognitive stage  
391 where the learner becomes aware of what has to be done to succeed by consciously  
392 processing the information, from the associative stage where the learner works on the  
393 different parts of the movement in an attempt to perform the task successfully (Fitts and

394 Posner 1967; Schmidt and Lee 2005). The findings of the current study showed, initially, (in  
395 lesson 2) how the VFB group succeeded in exploiting the augmented information from VFB  
396 in order to enhance awareness of their own vertical position. Second, use of VFB allowed  
397 them gradually to regulate their actions to significantly change their vertical alignment (by  
398 lesson 5).

### 399 *Changes in motivation*

400 Amotivation scores fell significantly for the experimental group between lesson 1 and  
401 lesson 5. According to Ryan and Deci (2000), amotivation represents a complete lack of  
402 intrinsic and extrinsic motivation, and is conveyed by a total absence of self-determination  
403 and willpower during task completion. According to this theoretical perspective,  
404 environments that generate a lack of three types of essential needs -autonomy, action  
405 effectiveness and peer-group affiliation- represent environments that are likely to create  
406 amotivation. In this study, the amotivation profile of the pupils in the experimental group  
407 dropped significantly in the space of five lessons, despite an initially low score after the first  
408 lesson ( $3.06 \pm 1.42$ ). According to Ntoumanis et al. (2004), the reasons proposed for  
409 amotivation in disengaged pupils (aged 14 and 15 years) during physical education lessons  
410 are linked to three factors: learned helplessness, non-consideration of their interests and  
411 needs, and the learning context. In the case of the latter, Ntoumanis and Biddle (1999) have  
412 highlighted the fact that a so-called 'mastery' learning climates, in which pupils feel able to  
413 progress by themselves, make it possible to avoid amotivation. The VFB learning aid, and the  
414 way it was implemented in this study, may have provided a context in which pupils felt they  
415 were playing an active role in their own learning. According to Shepard (2000), VFB  
416 combined with a self-assessment task can increase students' responsibility for their own  
417 learning and make relationships with teacher more collaborative. This could have been  
418 achieved by effectively allowing them to engage more in their own learning by continually  
419 readjusting their motor performance during learning by comparing their perceptions with the

420 reality of the video image.

421         A most important aspect of this engagement process, supported by VFB, was the  
422 creation of specific learning targets in collaboration with the teacher. According to Kingston  
423 and Wilson (2009), the multiple-goal approach (such as using self assessment and motor  
424 alignment goals) has the advantage that the potential negative effect of failing to achieve a  
425 target level of performance can be buffered by achieving other performance goals. Moreover,  
426 the constraints of this learning environment appear to meet the need for development of  
427 competence through more precise assessment of progress. Yet, the pupils' progress related to  
428 their vertical alignment performance did not become apparent until lesson 5. It would be  
429 interesting, in a future study, to study the motivational dynamics, lesson by lesson and week  
430 by week, in order to identify the effects of real progress on the different dimensions of  
431 motivation. It may also be the case that rapid progress in the self-assessment task also  
432 impacted the motivation profile of the experimental group with significant progress occurring  
433 as early as the second lesson, as opposed to the control group, which showed no progress in  
434 this aspect of the task.

435         As far as intrinsic motivation is concerned, results revealed considerably different  
436 development between the experimental group ( $ES = 0.26$ ) and the control group ( $ES = -0.31$ )  
437 as showed by the significant interaction group X time ( $H(1, 40) = 69.4; p < 0.01$ ). Post hoc  
438 tests, however, failed to highlight any statistically significant difference between lesson 1 and  
439 lesson 5 for both groups. This result refutes our initial expectation that VFB would provide  
440 information, which would increase intrinsic motivation in learning. Factors explaining this  
441 absence of significant progress may be linked to the limited autonomy pupils were given in  
442 accessing VFB. For teaching and class management purposes, the teacher in this study wholly  
443 managed VFB, and pupils could not choose what they watched or when they received it. In  
444 that respect, scientific evidence suggests that freedom of choice in the use of feedback fosters  
445 engagement and intrinsic motivation during learning (Janelle et al. 1997; Aiken, Fairbrother,

446 and Post 2012; Fairbrother, Laughlin, and Nguyen 2012; Patterson, Carter, and Hansen 2013;  
447 Hung et al., 2017). Future studies should take this important aspect of learning into account  
448 by giving pupils greater freedom in using VFB, allowing each participant the opportunity to  
449 access visual feedback on performance during learning whenever he/she wanted it.

450 *The use of a self-assessment task coupled with VFB in PE teaching.*

451 In the French educational system, syllabi for learning programs (including PE) are set  
452 nationally from kindergarden to senior high school, and structured around the notion of key  
453 competences. The use of Information and Communication Technology (ICT) is widely  
454 promoted, which makes VFB an appealing tool to develop pupil competencies. A competency  
455 can be defined as an integrated and stable network of knowledge and know-how, with  
456 normative behaviours, procedures and types of reasoning (Escalié et al. 2017). In order to  
457 develop these competencies, lesson plans often aim to integrate knowledge, skills and  
458 attitudes using a problem-solving approach. Competence-based teaching is believed to foster  
459 the transfer of learning from school to everyday life (De-Juanas, del Pozo, and Franco 2016).  
460 In the French PE curriculum, this competence-based approach is operationalized by  
461 integrating motor skills acquisition with methodological (method and tools for learning) and  
462 social (shape the individual and the citizens) competencies. In that respect, pupils have to  
463 develop these global competencies, as well as acquiring skills in different sports over  
464 relatively short periods of teaching (in general, 6-8 weeks). The results of our study  
465 reinforced the point that the use of self-assessment in a VFB task context helps learners to  
466 improve both their motor skills and their methodological competencies. It provides evidence  
467 to show that competency related to motor skill and self-assessment can be developed  
468 simultaneously in a short period of time.

469 Several studies (Palao et al. 2013; Weir and Connor 2009) have pointed out the  
470 reasons why VFB was not being used enough in PE contexts. According to these researchers,  
471 teachers often felt that VFB is time-consuming and detrimental to students' use of practice

472 time. Our study suggests that this kind of sheltered workshop organization might partly solve  
473 the problem, allowing teachers to safely oversee 75 skill attempts per person in five lessons  
474 while at the same time supervising the rest of the class.

#### 475 *Limitations and perspectives*

476 A possible limitation of this study, requiring future confirmation, is the absence of  
477 retention tests. Given that permission to conduct the study was granted on the condition that  
478 the yearly activity schedule for physical education lessons was not disrupted, it was  
479 impossible to plan a gymnastics lesson two weeks after the end of the course in the school  
480 timetable. A future study could monitor performance in vertical alignment, self-assessment  
481 and motivation two weeks after the end of the gymnastics course to observe whether  
482 significant differences between the two groups persisted. Additionally, a mixed method  
483 design, with qualitative data from semi-structured interviews with sub-samples of  
484 participants, would also help investigators understand participants' perception of VFB during  
485 the learning process and how relations with the teacher or others students could be influenced.  
486 The results of this study should also be interpreted carefully since the groups tested here were  
487 composed of novices in the gymnastic skill studied. Nevertheless, some pupils could have had  
488 previous experiences of activities that involved placing the body in a vertical reverse position  
489 or using VFB during their leisure activities. Recording overall extra-curricular gymnastic and  
490 VFB experiences for each participant in future studies is recommended to counter this  
491 possible limitation. According to the expertise reversal effect (Kalyuga 2007; Kalyuga et al.  
492 2003; Khacharem et al. 2014), levels of learner expertise may modulate the effectiveness of  
493 such means for enhancing learning. Caution should, therefore, be exercised in generalising  
494 these results, depending on learner levels. Last, this type of organization could be promoted  
495 with class-groups who display a fair level of autonomy in their schoolwork. Our setting  
496 allowed the teacher to supervise the entire class and focus on the regulation of the VFB  
497 workshop at the same time.

498 Future pedagogical and research challenges consist of examining the ways students  
499 could use VFB technology with more self-regulation and less reliance on teacher  
500 interventions. Recent studies, using digital tablets supporting self-regulation by the students,  
501 showed very good effects in the learning process and motivation in the acquisition of  
502 badminton skills and game strategies (Hung et al. 2017) or in learning to swim (Kretschman  
503 2017). Yet, as shown by Cohen, Goodway, and Lidor (2012), teachers might face challenges  
504 to provide an adequate level of self-regulated feedback to every kind of unexpected motor  
505 outcome. To overcome this problem, Post et al. (2016) used a split-screen replay with a video  
506 model compared with the VFB in the same frame. Results in a laboratory context showed  
507 significant effects on motor learning, motivation and perceived competencies. Testing this  
508 innovative proposal in a more ecological context is worth pursuing, providing the potential to  
509 further improve students' learning experiences.

510 As mentioned in several studies (e.g., Weir and Connor 2009; Palao et al. 2013), one  
511 barrier to enhance the use of new technology in PE teaching and improve pupil learning  
512 experiences, is linked to lack of confidence from the in teachers related to their own  
513 pedagogical-technology competency. In that respect, an important challenge in teacher  
514 training concerns the use of new technology by student teachers. In particular, the challenge  
515 concerns the sharing of pedagogical experiences about the use of ICT in different PE teaching  
516 contexts, as proposed, for example, by Casey, Goodyear, and Armour (2016). The current  
517 study hopefully helped to answer not only the 'how', but also the 'why' question, by  
518 promoting evidence-based grounds for use of VFB, thus justifying the need to analyse  
519 effectiveness of new pedagogical strategies using this tool.

520

## 521 **Conclusion**

522 Literature on the contribution of feedback in motor learning is extremely rich, but  
523 typically studied in controlled laboratory contexts during experiments. Focusing on its use in

524 real-life teaching conditions implies being fully conversant with the different dimensions of  
525 feedback and the multiple effects it can have depending on the learning stage. The results of  
526 this study showed how using a simplified video feedback-based learning aid, coupled with a  
527 self-assessment task, in real-life teaching conditions during an ongoing physical education  
528 program contributed to enhancing motor skills, self-assessment ability and motivation profiles  
529 over a short period of time in novices. As highlighted by Dutta and Bilbao-Osorio (2012), the  
530 question is not whether new technologies should be used or not. The scientific challenge is to  
531 try out the various technological solutions with the aim of making them levers of success in  
532 physical education programs to enhance the learning experience of individuals.

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