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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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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Abstract

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

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

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

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

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

Keyword*s*: feedback, pedagogy, video-based technology, learning, self-regulation.

Introduction

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

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

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

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

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

In this respect, numerous studies have demonstrated the effectiveness of VFB in the acquisition of various sports skills over relatively short learning periods, such as the golf swing (Guadagnoli, Holcomb, and Davis 2002), flip turns in swimming (Hazen et al. 1990), gymnastics (Merian and Baumberger 2007; Winfrey and Weeks 1993), soccer skills (Ziegler 1994), high jump (Mérian and Baumberger, 2007), diving (Thow, Naemi, and Sanders 2012), hang power clean in weightlifting (Rucci and Tomparowski 2010), spike jump in volleyball (Parsons and Alexander 2012) and hurdling (Palao et al. 2013). While results have highlighted the effectiveness of providing VFB on motor learning, the way it was used in studies varied depending on learning contexts. Since the study of Kernodle and Carlton (1992), results from research have shown that a combination of VFB, attentional information (focusing on a specific point of the movement) and verbal instructions represents a most functional pedagogical strategy for optimizing search activities during learning (Janelle et al. 1997; Rucci and Tomporowski 2010).

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

How can physical education specialists make sense of this laboratory-based research to enhance their everyday practice? Providing PE teachers with an increased number of digital tablets has led them to create learning aids based on presentation VFB (Gubacs-Collins and Juniu 2009; Kretschmann 2015). Nevertheless, studies seeking to measure the impact of these aids in real-life PE teaching programs are rare in comparison with sport settings (Palao et al. 2013; Ste-Marie et al 2012). Reasons for this void in the literature may include the lowest number of students in sport training groups, or that athletes and coaches theoretically have greater levels of investment in specific skill improvements (Guadagnoli, Holcomb, and Davis 2002; Smith and Loschner 2002); whereas PE teachers may emphasize different aims such as motor, cognitive, social, moral, spiritual or cultural development (Sallis and Mc Kenzie 1991). Additional disincentives for PE teachers to assess the efficacy of VFB may relate to time consuming pressures or economic issues (Norris, Soloway, and Sullivan 2002; Weir and Connor 2009).

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

To our knowledge, the few studies, which have sought to explore the impact of VFB on the learning experiences in PE setting have examined perceptions of learning using qualitative approaches (Palao et al. 2013). Kretchmann (2017) used a semi-structured interview methodology with students of 10 years of age, suggesting that they found VFB helpful for the learning process in swimming. With the same methodology, O'Loughlin, Chroinin, and O'Grady (2015) showed that VFB positively influenced self-reported motivation, self-assessment, and engagement when learning basketball skills in students aged 9-10 years. Also, Casey and Jones (2011) showed the effectiveness of using VFB in enhancing engagement with disaffected year seven students who developed greater depth of knowledge about throwing and catching skills. Others studies have confirmed a positive effect of VFB on motivation during PE learning (Potdevin et al. 2013; Weir and Connor 2009; Backaberg, 2016). According to Deci and Ryan’s Self-Determination Theory (SDT, 1985, 1991), information provided by VFB enhances perceived control of actions to be implemented and positively influences intrinsic motivation, which is vital for successful learning (Horn, 1987, 1992). Self-assessment tasks have been identified as a key pedagogy to enhance student achievement and motivation (Cauley and McMillan 2010; Hallam et al. 2004) by supporting learners' regulation of their own learning. To our knowledge, no study has explored the multiple effects of VFB on skill acquisition, self-assesment competencies, and motivation using quantitative data under the task constraints of a structured, school-based PE program.

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

Methods

Participants

Two classes of Year 7 pupils from the same French secondary school took part in the study during their gymnastics physical education lessons. The two classes of students were considered by their teachers to be autonomous and motivated during PE lessons. Video Feedback was offered to one class who acted as the experimental group, composed of 18 pupils (10 girls and eight boys, age = 12.4 ± 0.5 years old). The other class (control group) included 25 pupils (12 girls and 13 boys, age = 12.6 ± 0.4 years old). During the investigation, two pupils from each group were not present for one lesson. Informed consent was obtained from the students and the family of each participant concerning the nature of the research and the use of video images during lessons for the purposes of studying effects on learning. The Ethics Committee of the French Ministry of Education approved the research project on the condition that the study did not disrupt teaching or timetabling within the school day.

Protocol

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

The front handstand flat back exercise was part of each lesson and represented the only exercise where the participant's body was turned upside down. All students had no scholar or gymnastics club previous experience of activities that involved placing the body into a vertically aligned position. The aim of this exercise was for pupils to vertically align their bodies in an inverted vertical position (arms-trunk-legs), before letting themselves fall onto their back, keeping their bodies aligned until they hit the mat. During each lesson, pupils in both groups attempted the exercise 15 times. In other words each participant experienced 75 attempts over the five-week period.

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

****Figure 1 near here****

Material

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

Data collection

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

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

Self-assessment ability corresponds here to the ability to perceive one’s body in action. It is measured by the ability to judge one’s own performance and progress. As already mentioned, this self-evaluation process required pupils to answer a question in each lesson after the 5th attempt: ′Do you think you were in a straight line during this attempt? ′ as well as an additional question after the 10th and 15th attempts: ′Was your attempt better than the last time you watched it? ′ Finally, participants' self-assessment ability was evaluated via the five answers given each lesson, where each correct answer was awarded a point (resulting in a score out of five points).

Statistical analysis

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

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

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

Results

Significant improvement in motor skill performance from the fifth lesson onwards and enhanced self-assessment ability from the second lesson was observed in the experimental group. Similarly, a drop in amotivation scores between the first and the fifth lesson was revealed in the experimental group only.

Arm-trunk angle progression

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

****Figure 2 near here****

Self-assessment ability

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

****Figure 3 near here****

Changes in motivation scores

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

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

****Table 1 near here****

Discussion

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

Significant development of motor skills and self-assessment ability

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

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

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

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

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

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

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

Changes in motivation

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

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

As far as intrinsic motivation is concerned, results revealed considerably different development between the experimental group (ES = 0.26) and the control group (ES = -0,31) as showed by the significant interaction group X time ($H(1, 40) = 69.4$; $p < 0.01$). Post hoc tests, however, failed to highlight any statistically significant difference between lesson 1 and lesson 5 for both groups. This result refutes our initial expectation that VFB would provide information, which would increase intrinsic motivation in learning. Factors explaining this absence of significant progress may be linked to the limited autonomy pupils were given in accessing VFB. For teaching and class management purposes, the teacher in this study wholly managed VFB, and pupils could not choose what they watched or when they received it. In that respect, scientific evidence suggests that freedom of choice in the use of feedback fosters engagement and intrinsic motivation during learning (Janelle et al. 1997; Aiken, Fairbrother, and Post 2012; Fairbrother, Laughlin, and Nguyen 2012; Patterson, Carter, and Hansen 2013; Hung et al., 2017). Future studies should take this important aspect of learning into account by giving pupils greater freedom in using VFB, allowing each participant the opportunity to access visual feedback on performance during learning whenever he/she wanted it.

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

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

Several studies (Palao et al. 2013; Weir and Connor 2009) have pointed out the reasons why VFB was not being used enough in PE contexts. According to these researchers, teachers often felt that VFB is time-consuming and detrimental to students' use of practice time. Our study suggests that this kind of sheltered workshop organization might partly solve the problem, allowing teachers to safely oversee 75 skill attempts per person in five lessons while at the same time supervising the rest of the class.

Limitations and perspectives

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

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

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

Conclusion

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

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