Original Article

DOI: http://dx.doi.org/10.16926/par.2018.06.14

Effect of difficulty manipulation strategies on acquisition, retention and associated perceptions in fine motor coordination task learning in young school boys

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Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection

Abstract

This study investigated whether difficulty manipulation strategies affect learning in the fine motor coordination task, perceived competence (PC) and perceived difficulty (PD). Thirty-nine novices' right-handed boys (age 11.3 ± 0.4 years; stature 147 ± 8.94 cm; body mass 40.57 ± 0.07 kg; mean ± SD), volunteers, were assigned to either control group (CTG: no difficulty manipulation)and two experimental groups: group 1 (EG1: one-dimension difficulty manipulation) and group 2 (EG2: two-dimensions difficulty manipulation). All protocol sessions were conducted at the same time-of-day, in which, there were three periods: familiarization, acquisition and retention phases. Moreover, two stress-conditions of darts throw were investigated (i.e.: free condition (FC) and time pressure condition (TPC)). Results showed significant effect between-groups ($p = 0.01$, $\eta 2= 0.215$) based on difficulty strategies manipulation. Analysis showed an improvement in accuracy values in retention tests for only EG1and a significant lower coefficient of variation ($p = 0.41$, $\eta 2 = 0.154$) compared to the CTG and EG2. Errors decrease over time for CTG in FC ($p = 0.041$, $\eta 2= 0.203$) but not in TPC, while no significant differences in errors for EG1 and EG2 ($p = 0.19$, $\eta 2 = 0.911$) in the two stress-conditions. Moreover, PD was significantly different between all test-phases ($p = 0.041$, $\eta 2= 0.234$) for EG1 only. The one-dimension learning strategy improves retention in accuracy performances, whereas, both strategies, do not affect errors in both FC and TPC. Therefore, teachers in physical education are not encouraged to combine difficulties in learning process of a novel fine motor coordination task.

Keywords: motor learning, coordination, competence, difficulty.

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Recevied: 31.03.2018; Accepted: 23.04.2018; Published online: 6.06.2018

Cite this article as: Elghoul Y, Bahri F, Chaari N, Ezeddinie S, Masmoudi L, Souissi N, Frikha M. Effect of difficulty manipulation strategies on acquisition, retention and associated perceptions in fine motor coordination task learning in young school boys. Physical Activity Review 2018; 6: 100-109. doi: 10.16926/par.2018.06.14

INTRODUCTION

Motor learning is an important process during childhood. It allows development of a variety of fundamental movement patterns and more specialized motor skills [1]. Throwing competence, as fine motor coordination task, is considered as an important predictor of physical activity (PA) for children [2]. Researchers focused on skill acquisition are trying to recognize practice variables that allow optimization of the efficacy in motor learning. Manipulation of difficulty level is one, amongst others, of the learning strategies used to improve motor task performance [3-5]. In previous studies, task difficulty (TD) is defined as a subjective perception assessed by task doers [6]. Task complexity is sometimes used in an interchangeable sense with TD. It is assumed that the more complex a task is, the longer the subjects' response time will be, and there will be the lower accuracy rate [7]. Earlier results showed that performance is limited by TD, often in the form of a trade-off between speed and accuracy. Learning consists in breaking through this limit [8]. It was recently demonstrated that perceived TD increases when increasing difficulty in hand [5] and leg [9] aiming task performances, by creating a condition of moderate psychological stress.

In previous study [10], investigating the influence of gradual vs. sudden training during retention performance, the authors suggested that large difficulty increases in sudden protocol training, may not be necessary for learning a novel locomotors task. Likewise, it was demonstrated that TD during acquisition (bimanual coordination task) influences motor learning in older adults compared to young adults' sample [11]. Moreover, there is a significant negative correlation between perceived difficulty and executive function (EF) in situations requiring high difficulty levels [12]. The authors indicated that in normally developing children, motor performance and EF have several underlying processes in common that are related to planning, monitoring, detection and correction of errors. Earlier studies showed that the cognitive demands following error trials were higher than following successful trials in the golf putting task [13]. Cognitive demands were attributed to the adjustment of programs and to the implementation of corrective movements [13].

Manipulating TD (large vs. small target) is an intervention that is partially used to influence objective performance, success perceptions, perceptions of feedback error, interpretations of success during skill acquisition [14] or to find a suitable combination of the throwing distance and the size of a target for adult [15]. The results confirmed the fact that changes of target size influence on perception of success and self-efficacy [14]. However, this manipulation did not affect the interpretation of error feedback and performance in a delayed retention test. Findings from previous study validated the hypothesis that the smaller targets are, indeed, a bigger challenge for the participants than the larger ones [16]. Contrarily, in the dart throwing task, the authors postulated that better results were recorded while comparing the reduced field of view to increased field. Increased field would contain more visual stimuli distracting or irrelevant environment information to be processed [17].

Motor competence can be conceptualized as a person's ability to execute different motor tasks, including coordination of both fine (e.g. manual dexterity) and gross (e.g. static and dynamic balance) motor skills [18]. High levels of perceived competence (PC) have been strongly associated with adaptive motivational responses including more persistence [19] and performing better [19, 20]. Perceived task difficulty was generally negatively related to the PC [19]. Individuals, who perceive a task as more difficult develop lower levels of PC over time [21]. Limited research, however, has been exerted to investigate the role of perceptions of TD in relation to other constructs such as PC, cognitive processes [19] and factors predicting learning outcomes pressing [22].

Up to now, it remains unknown whether motor learning using different learning strategies, based on the manipulation of difficulty levels affects the retention of fine motor coordination task and the processes involving detections and correction of errors in relation with PC in young learners. In view of above considerations, the aim of the current study was to investigate the effect of gradual manipulation of difficulty levels (dartboard area: large vs. small and throw distances: long vs. short) on the performance of learning a novel fine motor coordination task and the relationships between learning strategies (i.e., gradual manipulation of difficulty levels), PC and PD in performing a throwing task in 11–12-year-old boys.

MATERIAL AND METHODS

Participants

Thirty-nine right-handed boys (age = 11.30 ± 0.4 years, body height = 147 ± 8.94 cm and body mass = 40.57 ± 0.07 kg; mean ± SD) volunteered to participate in this study. Participants had no previous experience of the tasks they were asked to perform. Different group were fixed with the constraint that participants were approximately matched to pre-test performance (i.e., throwing nine darts to strike as close as possible to the bull's eye), from the regular distance (i.e.: 2.37 m) [12, 14] and following two experimental stress conditions (with and without time-pressure) [5]. They were assigned to either a control group (CTG; n = 10); an experimental group 1 (EG1; n = 15), with difficulty level manipulated by increasing the distance from the dartboard; and an experimental group 2 (EG2; n = 14), with difficulty level manipulated by both reducing the dartboard dimension (45 cm; 30 cm; and 15 cm) and increasing the distance to the target (2 m; 2.37 m; and 3.56 m). The protocol was explained in full and a written informed consent was obtained from the children's parents. The study was conducted according to the declaration of Helsinki and the local Ethics Committee approved the protocol.

Procedures

The experiment took place during two sessions separated by one week. A pre-test followed by a phase of acquisition and immediate post-test during the first session and a delayed retention test a week later [14]. Test sessions were performed at the same time-of-day and after a 10 min standard warm-up including running and static stretching exercises [5], followed by three darts throws. In test session, two conditions were investigated. In the first, free condition (FC), subjects threw a trial of nine darts and were instructed always to aim for the bulls-eye. In the second, time pressure condition (TPC), participants was instructed to complete the set of throwing as quickly and accurately as possible [5, 12]. Darts areaswere the same and fixed in the same positions in all session tests. After each session, a PD questionnaire was completed by the subjects (DP-15).

Pre-Test: After pre-test trial and sessions, participants performed a PC questionnaire [23]. Pre-test consists of 9 trials. After the last trial, participants were invited to indicate their PD level.

Acquisition: Before acquisition trials, participants indicated their PC. While acquisition, which instantly ensued pre-testing, after each block, participant were asked to indicate their PD level. A total of 9 blocks was performed during acquisition.

Immediate post-test: The procedure in the post-test is identical to the pre-test consisting of 9 trials.

Delayed retention: The delayed retention test is identical to the post-test with participants performing 9 darts throws.

Throwing task and difficulty level manipulation

We modified difficulty level for the EG_1 by increasing the distance to the dartboard (one-dimension manipulation). Three distances were retained in this study: short one (i.e.: 2m), regular one (i.e.: 2.37m) and a long one (i.e.: 3.56m) according respectively [5, 12, 24]. The modification of difficulty level for the EG_2 was obtained by the manipulation of both distances to the target and dartboard area (two-dimension manipulation). Three areas were maintained in this experimental condition: 45 cm (regular); 30 cm; and 15 cm [17]. Therefore, relative to each distance (i.e.: 2m; 2.37 m; and 3.56 m), participants were invited to perform the dart throws to respectively the dartboard area. In each condition, dartboard size was regulated by covering the surface by black circle material from the side to the inside [17]. The CTG performed the same number of trial throw (nine throws by trial) with the same standard task (regular distance and official dartboard diameter). Individuals' posture and throwing techniques were maintained the same in the different conditions. The dartboard was fixed on a wall so that its center was at eye level for each subject [12].

Score calculations

Each throw was scored according to its position on the board (0–10). A dart that missed the board, or that bounced off was given a score of "0". The target consisted of a series of 10 concentric rings for the standard condition, and areas will be restrained in accordance with each experimentalcondition. Accuracy and consistency were evaluated by using three scores [12, 25]: the first was the mean score of the bloc throws. This score could range from 0 (all misses) to 10 (all bulls-eyes); a high score indicating high accuracy. The second measurement was the numbers of zeros scored (number of times the target was missedor bounced off). This score could range from 0 to 9. A low number of zeros indicates high accuracy. The third measure of performance was the coefficients of variation of the scores: [SD score]/[mean score]. A lower coefficient indicates a high consistency.

Measures

Perceived competence: PC was measured with one item: ‘‘How do you think you will perform in the follow-up task?’’ [23]. A 7-point scale was used (1=very poorly) to (7=very well).

Perceived difficulty: This scale is composed of 15 points numbered 1–15 and is anchored at the two extremities by verbal labels – “Extremely easy” and “Extremely difficult” [26].

Statistical analysis

All results are expressed as mean (± SD). As data were normally distributed, the calculated and measured variables were analyzed using three-way analysis of variance (ANOVA) with repeated measurements (to assess the effect of practice difficulty on dart performance indicators) and using two-way ANOVA repeated measures (to assess the effect of practice difficulty on cognitive comportments) for each data set (familiarization, acquisition and retention). When appropriate, significant differences among means were tested using Fisher LSD post hoc test. Correlations were used to assess the relationships between variables [27]. Effect sizes were calculated as partial eta-squared (η^2) to estimate the meaningfulness of significant findings. Partial eta squared value of 0.20, 0.50 and 0.80 represent small, moderate, and large effect sizes (respectively). The level of statistical significance was set at $p < 0.05$.

RESULTS

Performance measures

The strategy of TD manipulation was found to have a statisticallydifference between-group effect on the mean scores $F_{(2,38)} = 5.19$, $p = 0.01$, $\eta^2 = 0.215$. The post hoc analysis revealed that the mean scores of the group with one-dimension difficulty (Manipulation of the distance to the target; EG_1) showed a significant improvement inthe retention test when comparedto the control group ($p< 0.05$) (Figure 1). During the familiarization, acquisition and retention phases, the results reveal a significant main effect for learning on accuracy $F_{(2,76)} = 3.56$, $p = 0.033$, $\eta^2 = 0.086$, there is no significant main effect of time pressure condition $F_{(1,38)} = 0.75$, $p = 0.392$, $\eta^2 = 0.019$and no significant interaction difficulty strategy × motor learning × time pressure conditions $F_{(4,76)} = 0.24$; $p = 0.912$, $\eta^2= 0.013$.

A separate analysis was conducted on the mean scores for each group. There is a significant difference only in EG_1 $F_{(2,24)} = 3.67$, $p = 0.041$, $\eta^2 = 0.032$. The post hoc analysis showed an improvement in accuracy values in retention tests. Confirming the success of the strategy difficulty manipulation, the EG_1 (CV = 0.85, SD = 0.12) (one-dimension difficulty) made significantly lower mean scores for the coefficient of variation (CV: consistency measure) $F_{(2,38)} = 3.47$; $p = 0.41$, $\eta^2 = 0.154$ than the CTG and EG_2 (two-dimensions difficulty). Outcome consistency is shown in Figure2. Interestingly, participants with one-dimension task difficulty (EG_1), demonstrated significantly greater consistency compared with the other groups in the different tests (familiarization, acquisition and retention) $F_{(2,24)}= 4.32$; $p = 0.025$, $\eta^2 = 0.265$. The post hoc analysis revealed that the score of consistency for the EG_1 was better in retention than acquisition tests ($p < 0.05$). In addition, the statistical analysis showed significant negative correlations between the coefficient of variation and mean scores ($p< 0.01$).

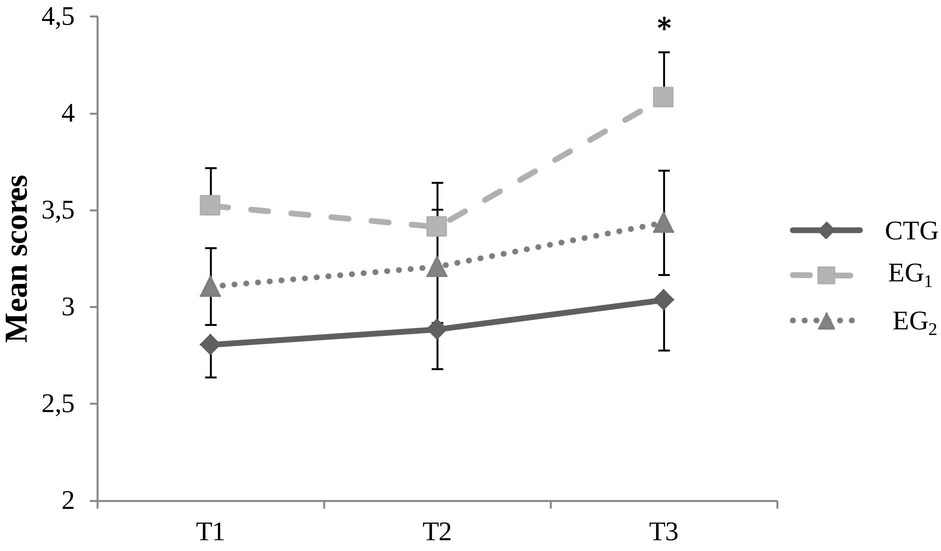

Figure 1. Accuracy as measured through mean scores in dart throwing task. CTG: control group; EG_1: experimental group 1; EG_2: experimental group 2; T1:*pre-test;* T2: *post-test*; T3: *retention test*. All values are mean ± SD. * Significant difference ($p < 0.05$)

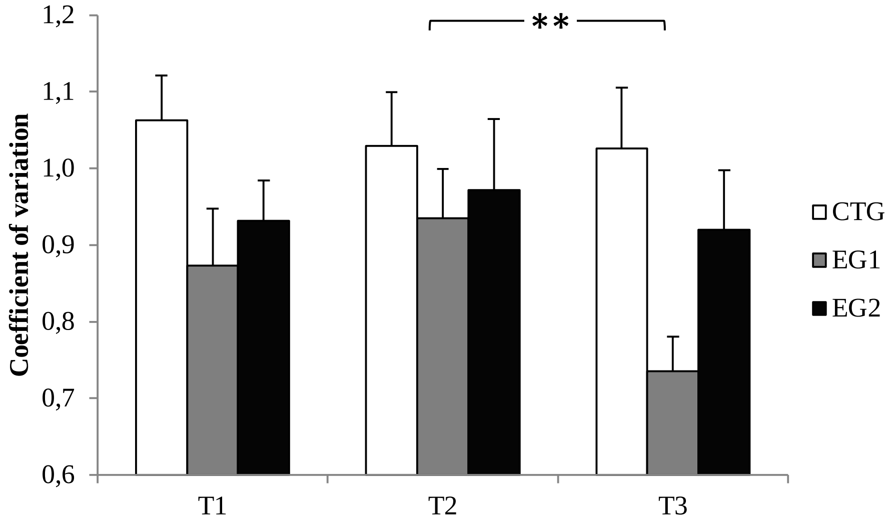

Figure 2. Consistency as measured through the coefficient of variation scores in dart throwing task. CTG: control group; EG1: experimental group 1; EG2: experimental group 2; T1: pre-test; T2: post-test; T3: retention test. All values are mean ± SD. * Significant difference ($p < 0.05$)

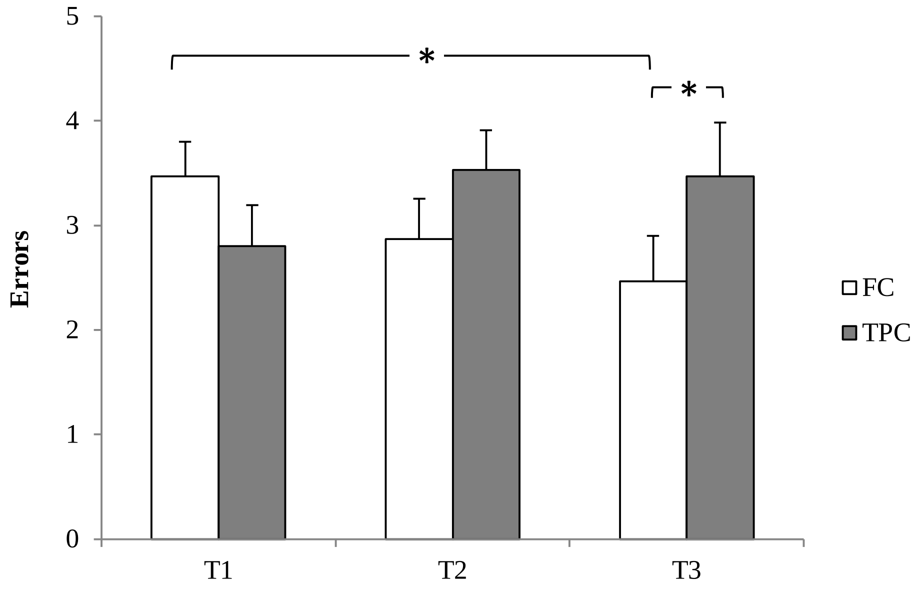

Figure 3. Accuracy as measured through the number of errors in dart throwing task. T1: pre-test; T2: post-test; T3: retention test. FC: normal condition; TPC: time pressure condition. All values are mean ± SD. * Significant difference ($p < 0.05$).

For error there was no significant main effect of difficulty strategy and no significant interaction (difficulty strategy × motor learning × time pressure conditions) $F_{(2,38)} = 2.89$; $p= 0.068$; $\eta^2= 0.0131$. The ANOVA with tow factor reveal a significant interaction only in the CTG (motor learning × time pressure conditions) $F_{(2,28)} = 3.58$;$p = 0.041$, $\eta^2= 0.203$. The post hoc analysis showed that the errors in the FC decrease over time, but that under TPC this precision measurement deteriorates (errors are significantly greater in T2 and T3 in comparison with T1). Moreover, analysis demonstrates that the errors of two groups EG_1 and EG_2 (different strategy of difficulty manipulation) does not differ significantly in different periods tests in the FC and TPC $F_{(2,24)} = 1.78$; $p = 0.19$, $\eta^2 = 0.911$ and $F_{(2,24)}= 0.03$;$p = 0.97$, $\eta^2 = 0.88$ (respectively). Compared between pre-test, post-test, and retention test, no significant results was supported with the large effect size.

Perceived difficulty

During the learning phases (familiarization, acquisition and retention), ANOVA did not reveal a significant, main effect on PD for difficulty strategy manipulation $F_{(2,38)} = 0.25$;$p = 0.777$, $\eta^2= 0.013$, on motor learning $F_{(2,76)} = 0.05$; $p = 0.95$, $\eta^2 = 0.001$andon pressure time $F_{(1,38)} = 0.84$, $p = 0.365$, $\eta^2= 0.021$. Given the lack of significance of the overall tests, ANOVA with tow factor on data's for each group were performed. Analysis demonstrates that PD of only EG_1 (one-dimension difficulty) differ significantly in different periods tests $F_{(2,24)} = 3.67$;$p = 0.041$, $\eta^2= 0.234$. Moreover, post hoc analysis revealed that the score of PD for only the EG_1 was significantly different between all tests-phases (T1, T2 and T3) ($p<0.05$). We also examined the relationships between performance measures and PD. A positive correlation was found between errors, coefficient of variation and PD ($p<0.001$); whereas we observe a negative correlation between mean score and PD ($p<0.001$). Importantly, the increase in performance measures was linked to one-dimension difficulty manipulation (EG_1) supported by the small effect size over all test periods.

Perceived competence

Analysis of two-factor variance showed a significant learning effect $F_{(2;76)} = 2.46$; $p = 0.02$; $\eta^2 = 0.215$. The post hoc test showed that the values of PC were significantly greater during the post-test than the pre-test in the three experimental groups at ($p< 0.05$).

DISCUSSION

The purpose of this study was to investigate the effect of gradual manipulation of difficulty levels (one-dimension difficulty: variation of distance to the target and two-dimensions difficulty: variation of both distance and target size) on the performance of learning a novel fine motor coordination task and the relationships between learning strategies (i.e., gradual manipulation of difficulty levels), PC and PD in performing a throwing task among 11–12-year-old boys.

The strategy using one-dimension difficulty enhanced learning in a novel psychomotor task. Despite the improvement observed in the two experimental groups during practice, only the group with a one-dimension of difficulty (EG_1) differs during the delayed retention test. Moreover, the performance improvement in accuracy (mean scores) differs significantly from T1, T2 and T3 (T1: post-test - pre-test; T2: retention test-pre-test; T3: retention test-post-test). In previous studies, improvement in accuracy was reported [28, 29], however, a recent study showed no enhancement of accuracy in the delayed darts throws retention test [14]. The group with one-dimension difficulty manipulation made significantly lower coefficient of variation (CV: consistency of measure) than the other groups. The CV decreased significantly from acquisition to retention for the same group (EG_1). Despite the fact that success in practice was translated to improve learning in the group one-dimension difficulty manipulation, strategy with target size manipulations does not improve learning. As there is limited research regarding the use of such strategy (i.e. target size manipulation), it appears that manipulations of large to small target do not translate success in practice to a permanent impact. The raises issues about the potential of relatively easy goals to transfer to positive and efficacy perceptions for more difficult goals [14].

In addition, the present investigation shows that progressive difficulty manipulation strategies do not affect errors. The analysis demonstrates that the error values of the two experimental groups do not differ in acquisition, retention as well as in FC and TPC. In a previous study, the authors confirmed that gradual training might reduce both TD and movement errors during practice, necessary for learning novel locomotor tasks [10]. In addition, progress with errors during the learning process, may have a positive effect on the mental model formation [30].

It is also important to point out that PD scores of only the group with one-dimension difficulty manipulation differ during practice and retention phase. The participants' perceived ratings in this group supported the thesis of increased effort in the task and affected performance [31]. In the current study, PD was correlated with the measurements performance of accuracy and consistency. It seems that the transfer of expertise acquired during the familiarization phase and acquisition towards more permanent performance is accompanied by a significant change in the PD scores when learning a novel psychomotor task. Learning consists of breaking through this limit [8]. Previous research suggests that adding difficulty to the instructional process can increase learning [32, 33]. While adding level difficulty to the learning process can often result in poorer performance during training [34].

The focal point of training is the retention of knowledge and ability manifested in delayed test performance in a novel and more difficult contexts [35]. Desirable difficulties are beneficial for learning since it promotes retrieval processes [36]. Past retrieval of stored information can promote retrieval processes in the future.

In this study, the underlying mechanism of improvements in learning a novel psychomotor task with one-dimension difficulty manipulation (i.e. Distance to target manipulation) may be related to cognitive task demands decreases; allowing extraction of relevant information and reducing errors necessary for learning. In relation to the present study, the strategy of difficulty manipulation allows to manage errors and this diminution is observed in TPC. On the contrary, accuracy performance (error) for the control group is reduced only for the easy throw condition (FC). It was found that the reduction of errors during acquisition encourages the use of implicit learning and may produce a higher subsequent level of golf putting performance in retention phase [37].

The notion of implicit learning provides another plausible explanation for the effect of using difficulty strategy manipulation on retention in the novel psychomotor task. Implicit learning refers to the acquisition of implicit knowledge [34]. This implicit knowledge can only be demonstrated through performance and not totally verbalized [38]. Furthermore, data support the hypothesis that learning predominantly occurred implicitly [34].

The present research provides initial insight into young people's PC in a relatively short learning period of a novel psychomotor task. The relative novelty of the task and the limited amount of time may limit significant improvements in performance [39]. The improvement in dart throwing performance registered in the retention phase for the group with one-dimension difficulty manipulation (EG_1) is not accompanied by an increase in PC. This finding is supported by the no-significant correlation between PC and the measure of precision and consistency in dart throwing performance. It is interesting to join finding, which authors mentioned that perceived task-specific competence did not predict performance [39]. Competence-based estimations are often poor predictors of performance for novel tasks [40]. Therefore, according to previous results and current findings; it appears that strategies of difficulty manipulations, based on progressive changes of distances to the target can improve learning of a novel psychomotor task. The perception of difficulty level can be used as an indicator in motor learning.

CONCLUSION

In summary, this study demonstrates that when learning to throw it is important that the program underpinning the learning process is well structured and suitable for the learner, their previous knowledge and is organized flawlessly. Incorrect steps during the first learning phases, related to task difficulty choices, can considerably extend the process of learning and then wasting a precious time.

The present findings show that both progressive difficulty manipulation strategies (one and two-dimensions difficulty manipulation) used, do not affect errors and this in both FC and TPC. The current study demonstrates that one-dimension difficulty manipulation leads to durable throwing accuracy and consistency performances. It seems that durability in accuracy performance was related to a significant decrease in PD scores for the same learned task. Consequently, teachers in physical education are not encouraged to combine difficulties in learning process of a novel fine motor coordination task. Further investigations concerning strategy with target size manipulations are needed.

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