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Cooperation enhances motor learning

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ABSTRACT

Relatedness represents the need to experience satisfaction from interpersonal acceptance and closeness with others and is considered a basic psychological human need. Studies testing the effects of supporting the learners' need for relatedness in motor learning (e.g., Gonzalez & Chiviacowsky, 2018) have manipulated relatedness basically by instructions from the experimenter and using practice and learning at an individual level. A different form of supporting the need for relatedness is through cooperative learning. In different domains, contexts involving cooperative effort strategies and goals were observed to result in greater positive interpersonal relationship and higher goal achievement in relation to individual efforts or competitive conditions. In this experiment, the effects of practice structured in cooperative or competitive ways on the learning of hitting a ball with a racket toward a target was tested. Adolescents practiced in pairs and were assigned to three experimental groups. In the cooperation group, the participants practiced in a cooperative condition while in the competitive group, the participants practiced in a competitive condition. Participants in a control group also practiced in the presence of another participant but were not induced at cooperative or competitive conditions. In the next day all groups performed retention and transfer tests. Questionnaires measured the participants' motivational and affective levels. The results show that cooperation increases intrinsic motivation, positive affect, self-efficacy, and task learning relative to individual efforts or competitive practice. Competition decreases perceived relatedness. The findings add to a growing body of evidence showing the importance of social relatedness for motor performance and learning. They also indicate a positive influential role of cooperation in motor learning.

1. Introduction

Numerous experiments from different lines of investigation suggest the important role of motivation in motor learning (for reviews, see Chiviacowsky, 2020, 2022; Lewthwaite & Wulf, 2012; Sanli, Patterson, Bray, & Lee, 2013; Wulf & Lewthwaite, 2016). Such studies have above all observed the effects of two motivational factors — autonomy (e.g., Andrieux, Danna, & Thon, 2012; Chiviacowsky & Wulf, 2002; Kaefer, Chiviacowsky, Meira Jr, & Tani, 2014; Laughlin et al., 2015) and competence support (e.g., Abbas & North, 2018; Chiviacowsky & Harter, 2015; Chiviacowsky & Wulf, 2007; Saemi, Porter, Ghotbi-Varzaneh, Zarghami, & Maleki, 2012) — on the acquisition of motor skills. Another motivational factor observed to benefit motor performance and learning is relatedness support (Chiviacowsky, Harter, Del Vecchio, & Abdollahipour, 2019; Gonzalez & Chiviacowsky, 2018; Kaefer & Chiviacowsky, 2021). Relatedness represents the need to experience satisfaction from interpersonal acceptance and closeness, instead of feeling ostracized or

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alienated (Ryan, 1995; Ryan & Deci, 2017); it is considered a necessary condition for optimal well-being, integrity, and functioning at several different levels (Deci & Ryan, 2000; Ryan, 1995). In line with the autonomy and competence psychological needs, relatedness is an important source of motivation for higher engagement, performance, and learning in different contexts and domains (Vansteenkiste, Ryan, & Soenens, 2020).

Notably, the studies observing relatedness effects on motor performance and learning have manipulated this factor through instructions from the experimenter and testing it at an individual level. Gonzalez and Chiviacowsky (2018), for example, provided two groups of participants learning individually a swimming task with instructions emphasizing interest, recognition, and the importance of the participants' experience, thus supporting the relatedness need, or instructions emphasizing disinterest in the participant as a person to frustrate learners feelings of relatedness. A third control group did not receive specific relatedness information. The relatedness support group showed higher learning than the other two groups. In addition, the relatedness frustration group underperformed when compared to the control group. Similar research designs and results were observed in experiments involving participants learning a forehand tennis stroke (Kaefer & Chiviacowsky, 2021), a gymnastic skill (Chiviacowsky et al., 2019), and a rehab pedalo locomotion task (Silva & Chiviacowsky, 2020) in different populations.

Considering the relevant effects of social relatedness in motor performance and learning, it would be useful to identify other conditions of practice that could potentially encourage positive social relationships, satisfying the participants' relatedness needs, as well as practice conditions that could frustrate the relatedness need satisfaction and should be avoided. One form of supporting relatedness is through cooperative learning (e.g., Ntoumanis, 2001). In cooperative goal strategies, an individual achieves their goal if—and only if—all other individuals also achieve it, resulting in enhanced interaction, greater effort to reach the goal, positive relationships, and better psychological adjustment and relationship satisfaction. Conversely in competitive goal strategies, an individual achieves his goal if—and only if—everyone else or the majority do not; the individuals work against each other to reach a goal that only one will reach, resulting in negative interpersonal relationships, psychological maladjustment, one individual's effort to obstruct the other's action, and relationship frustration (Deutsch, 1949; Johnson & Johnson, 2019).

In fact, in different domains, contexts that involve cooperative effort strategies and goals were observed to result in a more positive interpersonal relationship, greater social support, and goal achievement if compared to contexts that involve competitive effort strategies and goals, with the latter instead promoting negative interpersonal relationships (Bertucci, Johnson, Johnson, & Conte, 2016; Ghaith, 2003; Ghaith, Shaaban, & Harkous, 2007; Johnson & Johnson, 1989, 2009, 2010; Roseth, Johnson, & Johnson, 2008; Standage, Duda, & Pensgaard, 2005; Stanne, Johnson, & Johnson, 1999; Van Ryzin & Roseth, 2018). For instance, the impact of adopting cooperative strategies in satisfying the need for relatedness was observed in physical education classroom contexts (Casey & Goodyear, 2015; Méndez-Giménez, Fernández-Río, & Cecchini-Estrada, 2016). The effects were also found in distinct populations, including adolescents (Cecchini-Estrada, González González-Mesa, Llamedo, Sánchez Martínez, & Rodríguez Pérez, 2019; Fernández-Río, Sanz, Fernández-Cando, & Santos, 2016). Other studies have examined paired/dyad practice in motor learning at an individual (e.g., Granados & Wulf, 2007; Karlinsky, Alexander, & Hodges, 2022; Karlinsky & Hodges, 2014, 2018a, 2018b, 2019; Karlinsky, Welsh, & Hodges, 2019; Shea, Wulf, & Whltacre, 1999; Wulf, Clauss, Shea, & Whitacre, 2001) or team level (Chiviacowsky, 2020), or individual differences in motivation depending on cooperative vs. competitive scenarios in motor performance (e.g., Müller, Abad Borger, Kellermann, Wellnitz, & Cañal-Bruland, 2021; Müller & Cañal-Bruland, 2020a, 2020b). However, investigations into the effects of cooperative and competitive practice conditions on motor learning are still lacking.

The objective of the present experiment was, therefore, to verify the effects, if any, of cooperative and competitive structured practice contexts on motor performance and learning. In pairs, three groups of adolescents practiced a task of hitting a ball in a target with a racket on the first experimental day. Learning was tested individually the next day. While one group of participants practiced in a cooperative condition (relatedness support), another group practiced in a competitive condition (relatedness frustration). The third group (control) did not receive any relatedness instructions. It was also considered important to test mechanisms underlying cooperative and competitive effects on motor performance and learning. Higher levels of positive affect and intrinsic motivation were found in previous experiments using relatedness-supportive conditions relative to non-supportive practice conditions. (Gonzalez & Chiviacowsky, 2018; Kaefer & Chiviacowsky, 2021). Dopamine release, associated with positive affect and motivational effects, influences performance and learning through various pathways. Examples are playing a role in the process by which reward-related information influences the way people see themselves as agents (Aarts et al., 2012); increasing cognitive control and flexibility, facilitating creative problem solving (Ashby & Isen, 1999; Dreisbach & Goschke, 2004); improving reward-based decision learning (Ridderinkhof et al., 2012); and acting in memory consolidation or reinforcement, stamping-in memory traces associated with learning (Wise, 2004). Participants' levels of motivation and affect were, thus, assessed in the present experiment. It was hypothesized that enhanced motor performance and learning, and higher scores in intrinsic motivation and affective levels would be seen in the cooperative practice condition relative to the other conditions. There was also a possibility that the competitive group would demonstrate inferior results in all the measured variables relative to the control group.

2. Methods

2.1. Participants

Forty-eight adolescent students from a public school (24 boys, 24 girls), with a mean age of 15.4 years (SD = 1.3), participated in this study. Calculation of the sample size was carried out using G × Power 3.1, using F tests, with an α level of 5%, an effect size (f) of 0.60, and a power of 95% for the three groups; this matched the effect sizes previously reported using a similar study design (e.g., Kaefer & Chiviacowsky, 2021). Participants were not aware of the purpose of the study and had no previous experience with the task. A consent form was obtained both from the participants and their parents, and the Research Ethics Committee of the University approved this experiment.

2.2. Apparatus & task

In line with Kaefer and Chiviacowsky's (2021) study, participants were asked to perform forehand tennis strokes with their non-dominant arm, initiating the movements by themselves and using a wooden beach tennis racket. The goal was to hit a target placed on the floor (see Fig. 1) at a distance of 5 m from the participant (the center circle of the target had a radius of 10 cm and was surrounded by nine concentric circles, each one with a radius of 20, 30, 40… and 100 cm.). A score of 100 points was recorded when the ball first bounced in the center of the target; it was worth 90 points when the ball hit the next concentric circle, and so on. Zero points were given if the ball missed the target completely.

2.3. Procedure

Participants practiced in pairs and were randomly assigned to one of three experimental groups, but matched for gender (eight boys and eight girls in each experimental group, with same-gender pairs). Participants in the cooperation group (COO) practiced in a cooperative condition of practice, while the competitive group (COMP) practiced in a competitive condition. Participants in the control group were not induced at cooperative or competitive conditions. All participants received general instructions on the task and observed a demonstration before performing two pre-test trials. They were informed that the objective of the task was to hit the ball with the racket, attempting to hit the center of the target, all using the non-dominant hand. They were also informed that the foot on the opposite side of the hand that would hit the ball should be positioned forward. The pre-test was followed by a practice phase, which consisted of 60 trials. In the pre-test and the practice phases, while one of the pair's participants practiced, the other waited in the same environment, but without interacting with the pair's colleague and without visualizing their performance and their performance results. The following day, all groups performed retention (equal to practice) and transfer (7 m from the center of the target) tests, ten trials each, without the presence of the pair, and instructions referred only to the objective of the task (e.g., "Try to score as many points as possible"). The participants did not receive any form of augmented feedback in any experimental phase, but they could see the target and the ball flight in every trial.

The groups were manipulated upon receiving specific instructions after the pre-test and before starting the practice phase. Such instructions were based on previous studies (Fernández-Río et al., 2016; Johnson, Bjorkland, & Krotee, 1984), and on Deutsch's (1949), and Johnson and Johnson's (1974) definition of cooperative and competitive goal structure. Participants in the COO group received the following information: "You are part of the same team, so the score that each of you achieves will be added to form the pair's score". The COMP group, on the other hand, received the following instruction: "You will compete against each other, so the objective of each one is to score more points than the other". The control group received only the general instructions about the task. Participants then performed the 60 practice trials, receiving information to reinforce the manipulation after Trials 20 and 40. Participants in the COO group received the following information: "Remember you are a team, your score will form the total score for the pair" and "Remember the score of the two will form the total score of the team". At the end of the practice phase, they received the following information: "For today, your team's practice time is over. The points of each of you will be added up and this will form the total score of the pair". Participants in the COMP group received the following reminders information: "Remember you are competing against each other, so each one's goal is to score more points than the other" and "Remember you are competing against each other, so the objective of each one is to surpass the other". At the end of the practice phase, they received the following information: "For today, your competition is over, the points of each one will be separately added up and let's see who scored the most points".

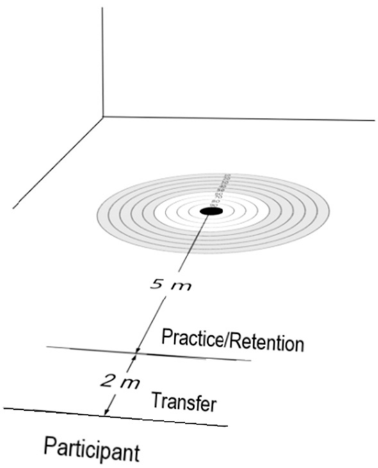

Fig. 1. Schematic of the target and zone areas (practice/retention and transfer) used by the participants when hitting the ball.

To measure intrinsic motivation, positive and negative levels of affect, and perceived self-efficacy after the pre-test and the practice phase, and before the retention test, the participants completed the Intrinsic Motivation Inventory (IMI) (McAuley, Duncan, & Tammen, 1989), the Brief Measures of Positive and Negative Affect (PANAS Scales) (Watson, Clark, & Tellegen, 1988), and the perception of self-efficacy questionnaire (Bandura, 2006), respectively. Participants were asked to rate their levels, on a scale of 1 ('not all true') to 7 ('very true'), of interest/enjoyment, perceived competence, effort, value/usefulness, pressure and tension, perceived choice, and relatedness (also serving as a manipulation check), in the IMI questionnaire. Each subscale was composed of four items and its final score was yielded by the average of the score achieved on the items; examples of the items included are: "After practicing this task for a while, I felt pretty competent" and "I enjoyed doing this activity very much". Internal consistency using Cronbach's (1951) coefficient alpha was found to be good for relatedness (0.876), value/usefulness (0.867), enjoyment (0.849), perceived choice (0.837), perceived competence (0.835), effort/importance (0.831), and the pressure/tension (0.713) subscales. In the PANAS questionnaire, participants were asked to rate, on a scale of 1 ('not at all') to 5 ('extremely'), words describing positive (ten words) and negative (ten words) emotions or feelings, depending on "how they feel now". To generate a single score of the positive and negative affect ratings, the ratings were also averaged. The ten task difficulty levels in the self-efficacy questionnaire were also averaged to yield a single score of the self-efficacy ratings, with the participants rating how confident they were that they would be able to achieve scores higher or equal to 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 points, on a scale of 1 (not at all) to 10 (very), during practice or the next day. At the end of the transfer phase, participants were informed about the objective of the study, debriefed, thanked, and released.

2.4. Data analysis

The accuracy scores (0–100) of the forehand stroke produced the main performance-dependent variable. The practice data—averaged across blocks of ten trials—were analyzed in a 3 (groups) × 6 (blocks) analysis of variance (ANOVA) with repeated measures on the last factor. One-way ANOVA was used for the pre-test, retention, and transfer tests, and also for each item of the IMI (McAuley et al., 1989), positive and negative affect (Watson et al., 1988), and perception of self-efficacy (Bandura, 2006) questionnaires. In addition, a 3 (groups) × 2 (tests: pre-test, retention/transfer) analysis of variance (ANOVA) with repeated measures on the last factor was used for differences in performance over time. Bonferroni post hoc tests were used for the follow-up analysis. Partial eta-squared values (η_p^2) were used to indicate effect sizes for significant results. The alpha was set at 0.05 for all analyses.

3. Results

3.1. Accuracy scores

3.1.1. Pre-test

During the pre-test, differences were not found between the groups, $F(2, 45) = 0.297$, $p = .744$, $\eta_p^2 = 0.013$, 95% CI [23.97, 29.36] (see Fig. 2).

3.1.2. Practice

The groups increased their accuracy scores across the practice phase (see Fig. 2). The main effect of block, $F(5, 225) = 46.397$, $p < .001$, $\eta_p^2 = 0.508$, was significant for blocks one, 95% CI [27.72, 33.73], two, 95% CI [36.31, 42.05], three, 95% CI [40.16, 45.41], four, 95% CI [41.13, 46.69], five, 95% CI [43.30, 47.61], and six, 95% CI [48.35, 53.14]. Post hoc tests confirmed differences, $p < .001$, between block one and blocks two, 95% CI [−10.62, −6.29], three, 95% CI [−15.03, −9.08], four, 95% CI [−16.53, −9.84], five, 95% CI [−17.88–9.08], and six, 95% CI [−22.67, −17.36], between block two and blocks four, $p = .028$, 95% CI [−9.16, −0.29], five, $p = .001$, 95% CI [−10.58, −1.95], and six, $p < .001$, 95% CI [−15.31, −7.81], between block three and block six, $p < .001$, 95% CI

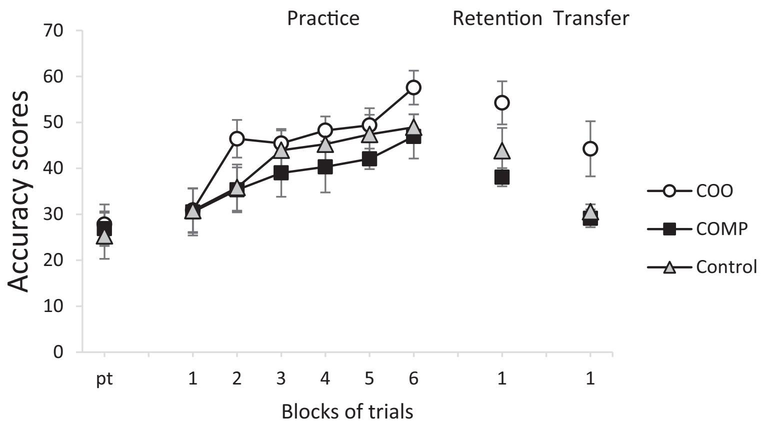

Fig. 2. Accuracy scores during practice, retention, and transfer for the Cooperation (COO), Competition (COMP), and Control groups. Error bars indicate 95% confidence intervals.

[−12.46, −3.44], between block four and block six, $p < .001$, 95% CI [−11.29, −2.37], and between block five and block six, $p = .003$, 95% CI [−9.37, −1.20]. The main effect of group was also significant, F (2, 45) = 6.171, $p = .004$, $\eta_p^2 = 0.215$, 95% CI [40.20, 44.07]. Post hoc tests confirmed that the COO group showed higher accuracy scores than the COMP group, $p = .001$, 95% CI [3.51, 12.98]. Differences were not found between COO and control groups, $p = .074$, 95% CI [−0.42, 9.03], or between COMP and control groups, $p = .100$, 95% CI [−8.67, 0.78]. The interaction of block and group was significant, F (10, 225) = 2.644, $p = .005$, $\eta_p^2 = 0.105$. Follow-up analyses in each group demonstrated a significant main effect of block for the COO group, F (5, 75) = 27.777, $p < .001$, $\eta_p^2 = 0.649$, 95% CI [43.55, 49.09], with differences, $p < .001$, between block one and blocks two, 95% CI [−23.27, −7.82], three, 95% CI [−22.72, −6.40], four, 95% CI [−28.19, −6.55], five, 95% CI [−28.97, −8.02], and six, 95% CI [−35.73, −17.63], between block two and block six, $p < .001$, 95% CI [−18.04, −4.21], between block three and blocks five, $p = .016$, 95% CI [−7.03, −0.84], and six, $p < .001$, 95% CI [−16.71, −7.53], between block four and block six, $p = .001$, 95% CI [−14.31, −4.30], and between block five and block six, $p = .003$, 95% CI [−13.04, −3.33]. For the COMP group, a significant main effect of block was also found, F (5, 75) = 6.678, $p < .001$, $\eta_p^2 = 0.308$, 95% CI [34.05, 42.08], with differences between block one and blocks two, $p = .007$, 95% CI [−14.23, −2.76], three, $p = .007$, 95% CI [−14.89, −0.60], four, $p = .035$, 95% CI [−14.89, −0.60], five, $p = .003$, 95% CI [−14.52, −3.73], and six, $p < .001$, 95% CI [−19.42, −11.07], between block two and block six, $p < .001$, 95% CI [−15.27, −5.60], between block three and block six, $p = .035$, 95% CI [−12.96, −0.54], between block four and block six, $p = .032$, 95% CI [−14.25, −0.74], and between block five and block six, $p = .032$, 95% CI [−11.63, −0.61]. A significant main effect of block was also found for the control group, F (5, 75) = 22.204, $p < .001$, $\eta_p^2 = 0.597$, 95% CI [38.30, 45.73]. Post hoc tests confirmed differences between block one and blocks two, $p = .013$, 95% CI [−8.78, −-1.21], and, $p < .001$, three, 95% CI [−18.72, −7.52], four, 95% CI [−18.66, −10.21], five, 95% CI [−22.06, −11.05], and six, 95% CI [−22.92, −13.32], and between block two, $p = .001$, and blocks three, 95% CI [−12.57, −3.67], four, 95% CI [−13.67, −5.19], five, 95% CI [−16.03, −7.08], and six, 95% CI [−17.42, −8.82].

3.1.3. Retention

The main effect of group was significant in the retention test, F (2, 45) = 14.360, $p < .001$, $\eta_p^2 = 0.390$, 95% CI [42.85, 47.89] (see Fig. 2). Post hoc tests showed higher accuracy scores for the COO group than the COMP, $p < .001$, 95% CI [8.76, 23.60], and control, $p = .004$, groups, 95% CI [3.01, 17.85]. COMP and control groups only marginally differed, $p = .067$, 95% CI [−13,17, 1.67].

3.1.4. Transfer

In the transfer test, significant differences between groups were also found, F (2, 45) = 17.791, $p < .001$, $\eta_p^2 = 0.442$, 95% CI [32.34, 36.94] (see Fig. 2). Post hoc tests showed higher accuracy scores for the COO group than the COMP, $p < .001$, 95% CI [8.34, 21.90], and control, $p < .001$, 95% CI [6.90, 20.47], groups. COMP and control groups did not differ, $p = .865$, 95% CI [−8.22, 5.34].

3.1.5. Differences over time

The main effect of pre-test to retention was significant for test, F (1, 45) = 127.351, $p < .001$, $\eta_p^2 = 0.739$, group, F (2, 45) = 6.713, $p = .003$, $\eta_p^2 = 0.230$, and interaction of test and group, F (2, 45) = 7.056, $p = .002$, $\eta_p^2 = 0.239$, revealing different performance patterns across tests for the experimental conditions. Post hoc tests confirmed that the COO group showed higher accuracy scores than the COMP, $p = .003$, 95% CI [2.50, 14.62], and the control, $p = .033$, 95% CI [0.41, 12.52], groups. Differences were not found between the COMP and control groups, $p = 1.000$, 95% CI [−8.15, 3.96]. Follow-up analysis for each group confirmed that the COO group showed higher improvement, F (1, 15) = 55.583, $p < .001$, $\eta_p^2 = 0.787$, 95% CI [37.56, 44.50], in accuracy scores from pre-test to retention, than the COMP, F (1, 15) = 27.854, $p < .001$, $\eta_p^2 = 0.650$, 95% CI [28.99, 35.93], and the control, F (1, 15) = 44.641, $p < .001$, $\eta_p^2 = 0.748$, 95% CI [31.09, 38.03], groups. For pre-test to transfer, the main effect was also significant for test, F (1, 45) = 21.381,

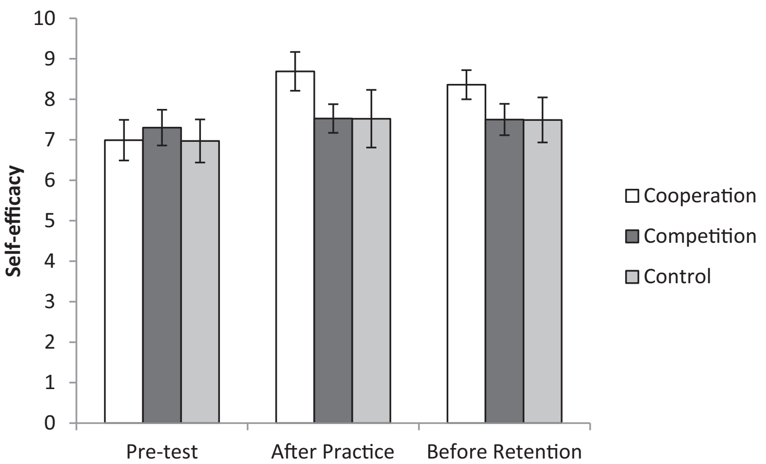

Fig. 3. Self-efficacy scores after the pre-test and practice, and before the retention test for the Cooperation, Competition, and Control groups. Error bars indicate 95% confidence intervals.

$p < .001$, $\eta_p^2 = 0.322$, group, $F\ (2, 45) = 8.991$, $p = .001$, $\eta_p^2 = 0.286$, and interaction of test and group, $F\ (2, 45) = 6.258$, $p = .004$, $\eta_p^2 = 0.218$. Post hoc tests demonstrated that the COO group again showed higher accuracy scores than the COMP, $p = .002$, 95% CI [2.57, 13.49], and the control, $p = .002$, 95% CI [2.63, 13.55], groups, while differences between the COMP and control groups, $p = 1.000$, 95% CI [−5.39, 5.52], were not found (see Fig. 2). Follow-up analysis in the different groups revealed that the COO group again showed higher improvement in accuracy scores from pre-test to transfer, $F\ (1, 15) = 15.558$, $p = .001$, $\eta_p^2 = 0.509$, 95% CI [32.90, 39.15], than the control group, $F\ (1, 15) = 5.601$, $p = .032$, $\eta_p^2 = 0.272$, 95% CI [24.81, 31.06], while difference from pre-test to transfer in the COMP group, $F\ (1, 15) = 1.122$, $p = .306$, $\eta_p^2 = 0.070$, 95% CI [24.87, 31.12], was not found (Fig. 2).

3.2. Self-efficacy

3.2.1. After pre-test

Differences were not found between the groups, $F\ (2, 45) = 0.512$, $p = .603$, $\eta_p^2 = 0.022$, 95% CI [6.78, 7.39], (see Fig. 3) after the pre-test.

3.2.2. After practice

Differences were found between the groups after practice, $F\ (2, 45) = 5.068$, $p = .010$, $\eta_p^2 = 0.184$, 95% CI [7.63, 8.29] (see Fig. 3). Post hoc tests showed higher self-efficacy levels for the COO group than the COMP, $p = .037$, 95% CI [0.95, 1.98], and control, $p = .015$, 95% CI [0.20, 2.13], groups. COMP and control groups did not differ, $p = .925$, 95% CI [−0.81, 1.11]. A significant positive correlation, controlling for group, was also found between self-efficacy after practice and performance on the last block of practice ($r = 0.304$, $p < .038$).

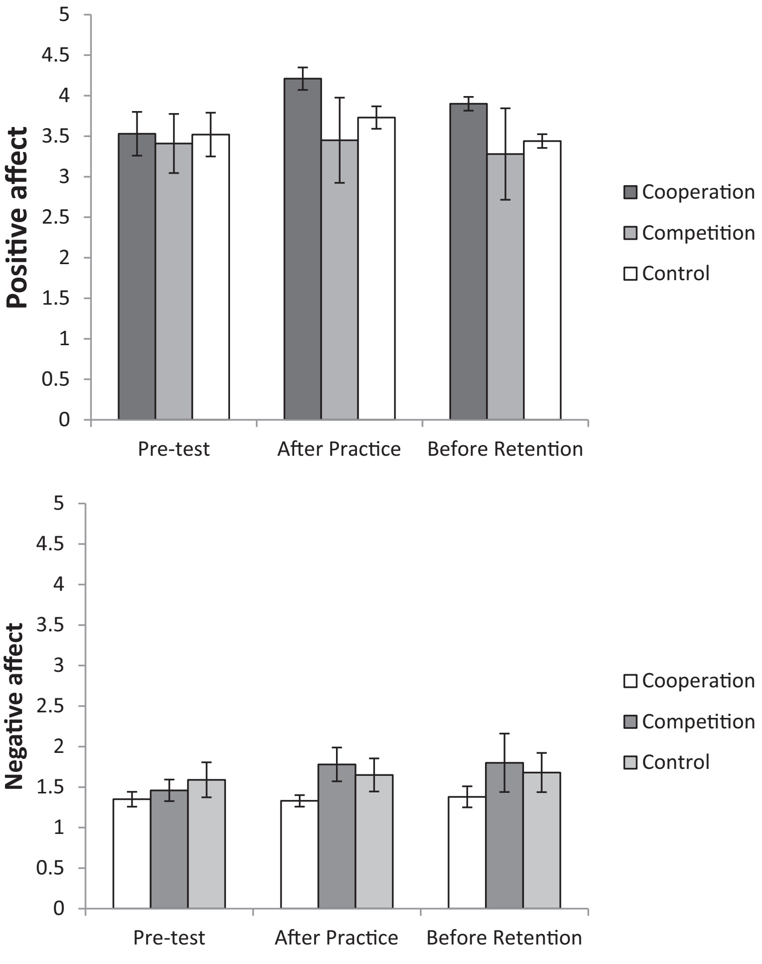

Fig. 4. Positive and negative affect scores after the pre-test and practice, and before the retention test for the Cooperation, Competition, and Control groups. Error bars indicate 95% confidence intervals.

3.2.3. Before retention

Differences were also found between the groups, F (2, 45) = 4.613, p = .015, η_p^2 = 0.170, 95% CI [7.51, 8.06] (see Fig. 3), before the retention test. Post hoc tests showed higher self-efficacy levels for the COO group than the COMP, p = .032, 95% CI [0.06, 1.66], and control, p = .029, groups, 95% CI [0.07, 1.67]. COMP and control groups did not differ, p = .999, 95% CI [−0.78, 0.81].

3.3. Positive & negative affect

3.3.1. After pre-test

Differences were not found between the groups (see Fig. 4) for positive, F (2, 45) = 0.159, p = .854, η_p^2 = 0.007, 95% CI [3.30, 3.68], or negative, F (2, 45) = 2.211, p = .121, η_p^2 = 0.089, 95% CI [1.37, 1.56], affect after the pre-test.

3.3.2. After practice

For positive affect, differences were found between the groups after practice, F (2, 45) = 4.031, p = .025, η_p^2 = 0.152, 95% CI [3.57, 4.02] (see Fig. 4). Post hoc tests showed higher affective levels for the COO group than the COMP group, p = .020, 95% CI [0.10, 1.40]. COOP and control groups did not differ, p = .186, 95% CI [−0.17, 1.13]. COMP and control groups also did not differ, p = .568, 95% CI [−0.92, 0.37]. For negative affect, differences were also found between the groups after practice, F (2, 45) = 6.365, p = .004, η_p^2 = 0.221, 95% CI [1.48, 1.69] (see Fig. 4). Post hoc tests showed higher negative affect levels for the COMP group relative to the COOP group, p = .003, 95% CI [−0.77, −0.12]. COOP and control groups were marginally significantly different, p = .051, 95% CI [−0.63, −0.01]. COMP and control groups did not differ, p = .541, 95% CI [−0.18, 0.45].

3.3.3. Before retention

Differences between the groups before retention were not found for positive F (2, 45) = 2.438, p = .099, η_p^2 = 0.098, 95% CI [3.30, 3.85], or negative, F (2, 45) = 2.450, p = .098, η_p^2 = 0.098, 95% CI [1.46, 1.78], affect (see Fig. 4).

3.4. Intrinsic motivation inventory

3.4.1. After pre-test

Differences between groups were not found in any of subscales after pre-test (see Table 1): interest/enjoyment, F (2, 45) = 0.760, p = .474, η_p^2 = 0.033, 95% CI [5.69, 6.30]; perceived competence, F (2, 45) = 1.184, p = .315, η_p^2 = 0.050, 95% CI [3.87, 4.65]; effort/importance, F (2, 45) = 0.186, p = .831, η_p^2 = 0.371, 95% CI [5.47, 6.13]; value/usefulness, F (2, 45) = 0.527, p = .594, η_p^2 = 0.023, 95%

Table 1
Means and standard deviations of the Intrinsic Motivation Inventory (IMI) scores after the pre-test and practice, and before the retention test for the Cooperation, Competition, and Control groups.

IMI Subscales		Groups	
		Cooperation	
	Pre-test	After Practice	Before Retention
Enjoyment	6.15 (0.57)	6.21 (0.56)	6.14 (0.45)
Competence	4.32 (1.38)	5.65 (0.72)	5.50 (0.40)
Effort	5.93 (0.91)	6.21 (0.75)	5.87 (0.82)
Tension	2.62 (1.26)	2.59 (1.17)	2.28 (0.97)
Choice	6.17 (1.23)	6.51 (0.55)	6.54 (0.77)
Value	6.09 (0.74)	6.15 (0.59)	5.70 (0.77)
Relatedness	6.18 (0.79)	6.59 (0.53)	6.64 (0.44)
		Competition	
	Pre-test	After Practice	Before Retention
Enjoyment	5.73 (1.50)	5.75 (0.39)	5.32 (0.93)
Competence	3.87 (1.48)	4.84 (1.04)	4.81 (0.74)
Effort	5.70 (1.55)	5.50 (1.00)	5.35 (1.10)
Tension	2.28 (0.98)	3.59 (1.02)	3.20 (1.07)
Choice	6.04 (1.22)	5.65 (1.07)	5.37 (1.20)
Value	5.75 (1.19)	5.43 (0.95)	5.54 (0.99)
Relatedness	6.04 (1.03)	5.31 (0.96)	5.07 (0.69)
		Control	
	Pre-test	After Practice	Before Retention
Enjoyment	6.10 (0.88)	6.15 (0.53)	5.60 (0.56)
Competence	4.59 (1.11)	5.09 (0.91)	5.01 (0.80)
Effort	5.76 (0.74)	5.60 (0.76)	5.53 (0.92)
Tension	2.39 (0.64)	2.78 (0.85)	2.67 (0.63)
Choice	5.87 (1.10)	5.95 (0.79)	5.90 (0.71)
Value	5.81 (1.03)	5.75 (0.56)	5.56 (0.61)
Relatedness	6.31 (1.13)	5.90 (1.06)	6.06 (1.17)

CI [5.59, 6.17]; pressure/ tension, F (2, 45) = 0.598, p = .554, η_p^2 = 0.026, 95% CI [2.16, 2.69]; perceived choice, F (2, 45) = 0.251, p = .779, η_p^2 = 0.011, 95% CI [5.68, 6.37]; and relatedness, F (2, 45) = 0.282, p = .755, η_p^2 = 0.012, 95% CI [5.89, 6.47].

3.4.2. *After practice*

Differences between groups after practice (see Table 1) were found in the subscales interest/enjoyment, F (2, 45) = 4.067, p = .024, η_p^2 = 0.153, 95% CI [5.89, 6.18]; perceived competence, F (2, 45) = 3.397, p = .042, η_p^2 = 0.131, 95% CI [4.93, 5.46]; effort/ importance, F (2, 45) = 3.338, p = .045, η_p^2 = 0.129, 95% CI [5.53, 6.02]; pressure/ tension, F (2, 45) = 4.287, p = .020, η_p^2 = 0.160, 95% CI [2.69, 3.28]; value/usefulness, F (2, 45) = 3.930, p = .027, η_p^2 = 0.149, 95% CI [5.57, 5.99]; perceived choice, F (2, 45) = 4.397, p = .018, η_p^2 = 0.163, 95% CI [5.80, 6.28]; and relatedness, F (2, 45) = 8.450, p = .001, η_p^2 = 0.273, 95% CI [5.68, 6.19]. Post hoc tests confirmed higher levels of enjoyment for the COOP group relative to the COMP group, p = .031, 95% CI [0.03, 0.90], higher levels of competence for the COOP group relative to the COMP group, p = .038, 95% CI [0.03, 1.58], higher levels of effort/importance for the COOP group relative to the COMP, p = .021, 95% CI [0.11, 1.32]; and control, p = .048, 95% CI [0.01, 1.21], groups, higher levels of pressure/ tension for the COMP group relative to the COOP, p = .008, 95% CI [0.26, 1.73]; and control, p = .030, 95% CI [0.08, 1.54], groups, higher levels of value/usefulness for the COOP group relative to the COMP group, p = .020, 95% CI [0.09, 1.34], higher levels of perceived choice for the COOP group relative to the COMP group, p = .015, 95% CI [0.14, 1.57], and higher levels of perceived relatedness for the COOP relative to the COMP, $p < .001$, 95% CI [0.52, 2.03], and control, p = .033, 95% CI [0.05, 1.31], groups.

3.4.3. *Before retention*

Differences between groups before retention (see Table 1) were also found in the subscales interest/enjoyment, F (2, 45) = 5.814, p = .006, η_p^2 = 0.205, 95% CI [5.49, 5.89]; perceived competence, F (2, 45) = 4.383, p = .018, η_p^2 = 0.163, 95% CI [4.91, 5.30]; pressure/ tension, F (2, 45) = 4.086, p = .023, η_p^2 = 0.154, 95% CI [2.45, 2.98]; perceived choice, F (2, 45) = 6.437, p = .003, η_p^2 = 0.222, 95% CI [5.67, 6.21]; and relatedness, F (2, 45) = 14.543, $p < .001$, η_p^2 = 0.393, 95% CI [5.68, 6.16]; but not in the subscales effort/importance, F (2, 45) = 1.204, p = .310, η_p^2 = 0.051, 95% CI [5.31, 5.86]; and value/usefulness, F (2, 45) = 0.181, p = .835, η_p^2 = 0.008, 95% CI [5.36, 5.84]. Post hoc tests confirmed higher levels of enjoyment for the COOP group relative to the COMP, p = .002, 95% CI [0.22, 1.39], and control, p = .033, 95% CI [−0.05, 1.11], groups, higher levels of competence for the COOP group relative to the COMP, p = .006, 95% CI [0.20, 1.16], and control, p = .048, 95% CI [0.01, 0.96], groups, lower levels of pressure/tension for the COOP group relative to the COMP group, p = .007, 95% CI [−1.57, −0.26], higher levels of perceived choice for the COOP group relative to the COMP group, p = .001, 95% CI [0.51, 1.83], and lower levels of perceived relatedness for the COMP relative to the COOP, $p < .001$, 95% CI [−2.15, −0.97], and control, p = .002, 95% CI [−1.57, −0.39], groups.

4. Discussion

The present experiment aimed to verify the effects of cooperation and competition on the performance and learning of a motor task in adolescents. Furthermore, potential mechanisms underlying the effects of cooperative and competitive practice were investigated. Our results appear to indicate that cooperation satisfies the basic psychological need for relatedness, enhancing task performance and learning relative to competitive or individual practice. The higher levels of relatedness fulfillment promoted by cooperation are in line with findings in different domains (Casey & Goodyear, 2015; Cecchini-Estrada et al., 2019; Méndez-Giménez et al., 2016). Supporting social relatedness by instructions provided by the experimenter was also observed to positively affect the performance and learning of motor tasks in adolescents (Kaefer & Chiviacowsky, 2021), young adults (Gonzalez & Chiviacowsky, 2018), and older adults (Silva & Chiviacowsky, 2020).

The higher rate of positive affect and a lower rate of the negative affect of participants practicing in a cooperative context also agree with the existing literature. Individuals who are in a cooperative or other relatedness supportive contexts have typically more positive attitudes toward other individuals, while more feelings of hostility and irritation toward the situation and other individuals are present in competitive and other relatedness thwarting practice contexts (Johnson, Maruyama, Johnson, Nelson, & Skon, 1981). Studies investigating the effects of social relatedness induced by instructions on motor skill learning observed higher rates of positive affect, and lower rates of negative affect in participants where relatedness was supported (Gonzalez & Chiviacowsky, 2018; Kaefer & Chiviacowsky, 2021; Silva & Chiviacowsky, 2020).

Positive affect increases dopamine release (Ridderinkhof et al., 2012). The dopaminergic system facilitates brain activities relevant to motor, cognitive, and motivational functioning (Hosp, Pekanovic, Rioult-Pedotti, & Luft, 2011; Menon, 2015; Nieoullon & Coquerel, 2003; Wise, 2004), helping the consolidation of long-term memory (Di Domenico & Ryan, 2017; Murty & Dickerson, 2016; Sugawara, Tanaka, Okazaki, Watanabe, & Sadato, 2012). Higher eye blink rates—a non-invasive neurobehavioral marker of dopaminergic activity (Aarts et al., 2012; Zhang et al., 2015)—was found in participants practicing a gymnastics motor skill in a supportive relative to a frustrated relatedness condition (Chiviacowsky et al., 2019).

Cooperation in the present experiment also resulted in enhanced perceptions of self-efficacy and intrinsic motivation, relative to the other groups. In other domains, contexts with cooperative experiences have been observed to promote greater perceived self-efficacy and motivation (Cecchini-Estrada et al., 2019; Johnson, Johnson, Pierson, & Lyons, 1985; Moreno, González-Cutre, & Sicilia, 2008; Peng & Hsieh, 2012) if compared to contexts with competitive experiences. Cooperative contexts creating positive patterns of group interactions or social bonds can even help mitigate negative effects of reward-removal on learning, relative to individual contexts (Sears & Pai, 2012). The sense of belonging and relatedness satisfaction was observed to predict both perceived self-efficacy and intrinsic motivation in adolescents (Freeman, Anderman, & Jensen, 2007; Kim & Keller, 2008; Usher & Pajares, 2009; Zumbrunn, McKim, Buhs, & Hawley, 2014). Self-efficacy, in turn, predicts motor performance (Feltz, Chow, & Hepler, 2008; Moritz, Feltz, Fahrbach, & Mack, 2000; Rosenqvist & Skans, 2015) and learning (Chiviacowsky, Wulf, & Lewthwaite, 2012; Pascua, Wulf, & Lewthwaite, 2015; Stevens, Anderson, O'Dwyer, & Williams, 2012; Wulf, Chiviacowsky, & Cardozo, 2014). Likewise, the group practicing in a cooperative condition showed higher intrinsic motivation, including increased levels of enjoyment, competence, choice, and importance of doing well, relative to the other groups. Similar results were found in previous motor learning studies manipulating relatedness support in adults (Chiviacowsky et al., 2019; Gonzalez & Chiviacowsky, 2018) and adolescents (Kaefer & Chiviacowsky, 2021). Positive perceptions of teacher-student relationships have been associated with higher perceived autonomy and competence in other domains as well (e.g., Bakadorova & Raufelder, 2018).

In conclusion, the present experiment provides the first evidence that a context based on cooperation between individuals, thus satisfying the need for relatedness, enhances motor learning. More specifically, cooperative practice—promoting positive social relationships—positively affects intrinsic motivation, affective levels, self-efficacy, and the performance and learning of motor skills in adolescents relative to competitive or individual conditions of practice. Future research could investigate the generalization of these results in other types of tasks and practice contexts, as well as in different populations with, for example, distinct ages, levels of expertise, or health conditions. One limitation of the present study was the use of a one-dimensional accuracy measure. As such, it would be important if future studies could also observe participants' consistency, measuring the two-dimensional bivariate variable error (VE; e.g., Hancock, Butler, & Fischman, 1995). Other complementary performance measures, such as surface electromyography (EMG) and motion analysis (e.g., Lohse, Sherwood, & Healy, 2010), could also be used. Moreover, a more direct manipulation check could be applied to observe what control participants focused on during practice (e.g., competing against the pair). In addition, the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016) acknowledges that two motivational factors (autonomy support and enhanced expectancies for successful performance) can independently and additively (e.g., Wulf et al., 2014; Wulf, Lewthwaite, Cardozo, & Chiviacowsky, 2018) contribute to motor learning. Considering recent research showing relatedness support as an important independent motivational factor in motor performance and learning, future studies could test if relatedness combined with each one of the two other factors (autonomy support or enhanced expectancies)—or even the three factors together—would additively benefit motor performance and learning in comparison to only one, or the addition of the two other, motivational factors.

CRediT authorship contribution statement

Angélica Kaefer: Conceptualization, Methodology, Data curation, Writing – original draft. **Suzete Chiviacowsky:** Conceptualization, Methodology, Data curation, Writing – original draft, Writing – review & editing, Supervision.

Declaration of Competing Interest

None.

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