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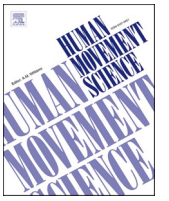

Relatedness support enhances motivation, positive affect, and motor learning in adolescents

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ABSTRACT

Social relatedness is a basic psychological need to experience satisfaction of interpersonal acceptance and closeness with others. In this experiment, the effects of social relatedness on the learning of a task (hitting a ball with a racket toward a target) were tested in adolescents. Participants were assigned to three experimental groups. After a pre-test and before practice, participants in the relatedness support (RS) condition received instructions emphasizing recognition, importance, and interest in the participant's experience. Participants in the relatedness frustration (RF) condition received instructions emphasizing disinterest in the participant as a person. Control participants did not receive specific relatedness instructions. One day later, they performed retention and transfer tests. Questionnaires measured participants' motivational and affective levels. The results showed that supporting the relatedness need enhances task learning in adolescents. Motivation and affective levels were also affected. The findings are the first to show that social relatedness affects adolescent's motor performance and learning and reveal underlying mechanisms implicated in such effects.

1. Introduction

Research observing the role of motivation on motor learning has grown over the last two decades (for reviews, see Chiviacowsky, 2020; Lewthwaite & Wulf, 2012; Sanli, Patterson, Bray, & Lee, 2013). Self Determination Theory (Ryan & Deci, 2017, 2019), in particular its micro-theory of basic psychological needs, and the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016) have provided frames of reference to explain the effects of motivation on the learning of motor skills. Autonomy, competence, and relatedness are basic psychological needs, and sources of motivation for higher engagement, performance, and learning in a variety of contexts (Xiang, Ağbuğa, Liu, & McBride, 2017). The three needs are considered necessary conditions for optimal integrity, well-being, and functioning at a physiological, psychological, and social level (Deci & Ryan, 2000; Ryan, 1995; Vansteenkiste, Niemiec, & Soenens, 2010).

Relatedness represents the need to experience satisfaction from interpersonal acceptance and closeness, rather than feeling alienated or ostracized; together with autonomy and competence, it is considered a basic psychological human need (Ryan, 1995; Ryan & Deci, 2017). While several studies have observed positive effects on the learning of motor skills in practice contexts supporting the learner's needs for autonomy (Aiken, Fairbrother, & Post, 2012; Andrieux, Danna, & Thon, 2012; Chiviacowsky, 2014; Chiviacowsky & Wulf, 2002; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Kaefer, Chiviacowsky, Meira Jr, & Tani, 2014; Laughlin et al.,

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2015) and competence (Abbas & North, 2018; Chiviacowsky & Harter, 2015; Chiviacowsky & Wulf, 2007; Gonçalves, Cardozo, Valentini, & Chiviacowsky, 2018; Saemi, Porter, Ghotbi-Varzaneh, Zarghami, & Maleki, 2012), only three studies in the existing body of literature have looked at the effects of relatedness support on motor learning. In these three experiments, positive effects of practice with relatedness support were found in young adult participants learning a speed swimming task (Gonzalez & Chiviacowsky, 2018) or a gymnastic task (Chiviacowsky, Harter, Del Vecchio, & Abdollahipour, 2019), and also in older adults learning the dynamic balance task of riding a rehab pedalo over a set distance (Silva & Chiviacowsky, 2020).

The dearth of studies looking at the effects of relatedness in motor learning point to the importance of further examining the influence of instructions supporting or frustrating the need for relatedness on skill learning, especially in different populations; for example, adolescents. The adolescence period is characterized by a confluence of biological, psychological, and social challenges (Huizhen, 2014; Lei, Cui, & Chiu, 2018; Lord, Eccles, & McCarthy, 1994), where physical, emotional, and cognitive development are intense (Hattie, 1992; Steinberg, 2005). These transformations affect the way adolescents relate to others, also reflecting a higher independence of psychological and emotional development from parents, with a correspondingly growing dependence on relationships with peers or other adults (Collins & Steinberg, 2006; Furman & Buhrmester, 1992; Scholte, Van Lieshout, & Van Aken, 2001; Steinberg, 1990; Wentzel, 1998).

Notably, the occurrence of a decline in motivation is well documented at the adolescence stage (Eccles, 1994; Eccles & Roeser, 2011; Eccles, Wigfield, & Schiefele, 1998; Kim, Oesterle, Catalano, & Hawkins, 2015; Roeser & Eccles, 1998; Roeser, Eccles, & Sameroff, 1998). Students have demonstrated less autonomous motivation and less perception of self-efficacy, for instance, when there is a decrease in interpersonal relationships with teachers (Feldlaufer, Midgley, & Eccles, 1988; Hirsch & Rapkin, 1987). Contrarily, adolescents experience a greater sense of well-being (Baroody, Rimm-Kaufman, Larsen, & Curby, 2014; García-Moya, Brooks, Morgan, & Moreno, 2015; Liu, Li, Chen, & Qu, 2015; Pössel, Rudasill, Sawyer, Spence, & Bjerg, 2013; Rueger, Malecki, & Demaray, 2010) and engagement (Chen, Hughes, Liew, & Kwok, 2010; Li, Lynch, Kalvin, Liu, & Lerner, 2011; Wentzel, 2009; Wentzel, Battle, Russell, & Looney, 2010), a higher quality of motivation (Anderman & Anderman, 1999; Bakadorova & Raufelder, 2018; Battistich, Solomon, Watson, & Schaps, 1997; Hamm & Faircloth, 2005; Nelson & DeBacker, 2008; Patrick, Hicks, & Ryan, 1997; Ryan & Grolnick, 1986; Sánchez, Colón, & Esparza, 2005; Wentzel, Muenks, McNeish, & Russell, 2017; Wubbels, Brekelmans, Mainhard, den Brok, & Tartwijk, van, J. W. F., 2016; Xiang et al., 2017), greater academic success (Cappella, Kim, Neal, & Jackson, 2013; Furrer & Skinner, 2003; Roorda, Koomen, Spilt, & Oort, 2011), and also higher levels of positive affect (Ryan, Stiller, & Lynch, 1994; Sheldon & Filak, 2008) when relatedness is supported through teachers, parents, colleagues, or coaches.

In this context of transformation and the easy decline in motivation, the support of basic psychological needs — including relatedness — becomes fundamental for optimal functioning and development in this population (Bakadorova & Raufelder, 2018; Deci & Ryan, 2000). The objective of the present experiment was, therefore, to investigate whether social relatedness can affect the learning of a motor skill in adolescents. Three groups of adolescents practiced the task of hitting a tennis ball with a wood racket in order to hit a target. While one group of participants received instructions emphasizing interest, recognition, and the importance of the participants' experience (relatedness support), another group received instructions emphasizing a disinterest in the participant as a person (relatedness frustration). A third group (control) did not receive any relatedness instructions.

We also considered it important to look at the potential mechanisms that underlie the relatedness effects on adolescents' learning. In Gonzalez and Chiviacowsky's (2018) research, adults practicing in a relatedness support condition not only demonstrated higher learning but also reported higher levels of positive affect and intrinsic motivation relative to participants practicing without relatedness support. Positive affect has been strongly associated with dopamine release, and is considered to influence performance and learning through various dopaminergic pathways (Aarts et al., 2012; Ashby & Isen, 1999; Dreisbach & Goschke, 2004; Ridderinkhof et al., 2012). Higher scores of self-efficacy and positive affect were also found for the relatedness support group in older adults (Silva & Chiviacowsky, 2020). Thus, in the present experiment, participants' levels of motivation and affect were also assessed. We hypothesized higher scores in perceived self-efficacy, intrinsic motivation, and affective levels, and enhanced skill learning for the relatedness support condition relative to the other conditions. It was also expected that the control group would demonstrate better results in all the measured variables relative to the relatedness frustration group.

2. Methods

2.1. Participants

Forty-five adolescents, students from a public school (24 boys, 21 girls), with a mean age of 14.8 years (SD = 1.2) 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%, effect size (f) of 0.49, and a power of 81.75% for the three groups, based on effect sizes previously reported using similar study design (e.g., Gonzalez & Chiviacowsky, 2018). Participants had no previous experience with the task, nor were they aware of the purpose of the study. The Research Ethics Committee of the University approved this experiment, and a consent form was obtained both from the participants and their parents.

2.2. Apparatus & task

Participants were asked to perform forehand tennis strokes with their non-dominant arm, using a wooden beach tennis racket, initiating the movements by themselves (closed motor skill). The goal, similar to previous studies (e.g., Singh & Wulf, 2020), was to hit a target (see Fig. 1) placed on the floor, 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. When the ball first bounced in the center of the target, a score of 100 points was recorded; when the ball hit the next concentric circle, it was worth 90 points, and so on. If the ball missed the target completely, zero points were given.

2.3. Procedure

Participants were randomly assigned to three experimental conditions: relatedness support (RS) group, relatedness frustration (RF) group and the control group. Before performing two pre-test trials, the participants received general instructions of the task, observed a demonstration, and were informed that the objective of the task was to hit the ball with the racket, using the non-dominant hand, and attempt to hit the center of the target.

After the pre-test and before starting the practice phase, the groups were manipulated upon receiving specific relatedness instructions. Such instructions were based on previous studies that tested relatedness effect manipulations on adults (e.g., Gonzalez & Chiviacowsky, 2018; Sheldon & Filak, 2008) and on the definition of the relatedness need described by Ryan and Deci (2017). The RS group received the following information: "It is important for you to know that, for us, each one of you is unique. We care about everyone as an individual, and we are trying to understand each person's way of learning. So, we care about you and your way of learning. Feel free to talk about your thoughts while performing this task after the experiment is finished, if you want." The RF group received the following instruction: "It is important for you to know that, for us, all participants are equal. We are not interested in you as an individual and your reactions and feelings. We are only interested in the data, in our experiment, that is, in what you will do here. Please keep your comments and feelings for yourself during the activities." The control group did not receive specific relatedness instructions.

Participants then performed 60 practice trials. After trials 20 and 40, participants in the RS and RF groups received information to reinforce the manipulation. The participants of the RS group received the following information: "Just to remember: feel free if you want to tell us something about the accomplishment of this task and how you felt, after the end of the experiment". The RF group received the following information: "Just to remember: we are not interested in your reactions and your individual learning style. Please keep your questions and comments to yourself." The next day, all participants performed retention (equal to practice) and transfer (7 m from the center of the target) tests — ten trials each.

In order to measure positive and negative levels of affect, perceived self-efficacy, and intrinsic motivation, after the pre-test and the practice phase, and before the retention test, the participants completed the Brief Measures of Positive and Negative Affect (PANAS Scales) (Watson, Clark, & Tellegen, 1988), the perception of self-efficacy questionnaire (Bandura, 2006), and the Intrinsic Motivation

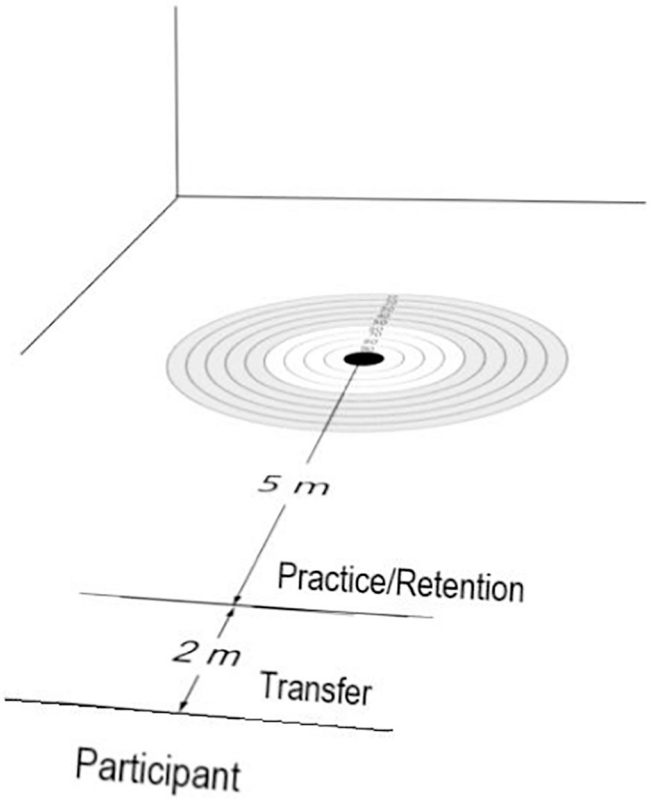

Fig. 1. Schematic of the target and zone areas (practice/retention and transfer) used by the participants when hitting the ball.

Inventory (IMI) (McAuley, Duncan, & Tammen, 1989), respectively. In the latter, participants were asked to rate their levels of interest/enjoyment, perceived competence, effort, value/usefulness, pressure and tension, perceived choice, and relatedness (also serving as a manipulation check) on a scale of 1 (not all true) to 7 (very true). 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". Each subscale was composed of four items and its final score was yielded by the average of the score achieved on the items. Negatively worded items were re-scored before data analysis. Internal consistency using Cronbach's (1951) coefficient alpha was found to be excellent for value/usefulness (0.936) and effort/importance (0.910) subscales, and good for perceived competence (0.889), enjoyment (0.872), pressure/tension (0.825), perceived choice (0.824), and the relatedness (0.739) subscales. In the self-efficacy questionnaire, the participants rated how confident they were that they would be able to achieve, during practice or on the next day, 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). The ten task difficulty levels were averaged to yield a single score of the self-efficacy ratings. In the PANAS questionnaire, participants were asked to rate words describing positive (ten words) and negative (ten words) feelings or emotions, on a scale of 1 (not at all) to 5 (extremely), depending on "how they feel at the present moment". The ratings were also averaged to generate a single score of the positive and negative affect ratings. At the end of the transfer phase, participants were debriefed, informed about the objective of the study, thanked, and released. Despite the relatedness support instructions, none of the participants in the RS group shared thoughts or feelings after practice.

2.4. Data analysis

Our measure of forehand stroke performance was the accuracy score (0−100). The practice data were averaged across blocks of ten trials and 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. Three (groups) x 3 (time) separated mixed ANOVAs with repeated measures on the last factor were used for each item of the IMI (McAuley et al., 1989), perception of self-efficacy (Bandura, 2006), and positive and negative affect (Watson et al., 1988) questionnaires. For the purposes of a follow-up analysis, a one-way ANOVA with repeated-measures and paired-sample *t*-tests between each time point were conducted for each group. In addition, Pearson correlations were used to examine the relationship between psychological variables and learning, controlling for group. In order to indicate effect sizes for significant results, partial eta-squared values (η_p^2) were used. The alpha was set at 0.05 for all analyses.

3. Results

3.1. Accuracy scores

3.1.1. Pre-test

Differences were not found between the groups during the pre-test, F (2, 42) = 0.261, p = .771, η_p^2 = 0.012 (Fig. 2)

3.1.2. Practice

All groups increased their accuracy scores across the practice phase (see Fig. 2). The main effect of block, F (5, 210) = 11.387, p < .001, η_p^2 = 0.213, was significant. Post hoc tests confirmed differences between block 1 and all other blocks, p < .001, and between block 2 and block 6, p = .023. The main effect of group was also significant, F (2, 42) = 5.700, p = .006, η_p^2 = 0.213. Post hoc tests confirmed that the RS group showed higher accuracy scores than the RF, p = .012, and control, p = .019, groups, while RF and control groups did not differ, p = .985. The interaction of block and group was not significant, F (10,210) = 1.466, p = .154, η_p^2 = 0.065.

3.1.3. Retention

The main effect of group was significant in the retention test, F (2, 42) = 34.529, p < .001, η_p^2 = 0.622 (Fig. 2). Post hoc tests showed higher accuracy scores for the RS group than the RF, p < .001, and control, p < .001. RF and control groups did not differ, p =

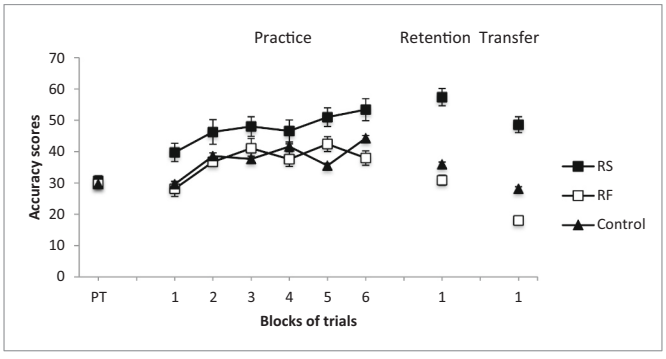

Fig. 2. Accuracy scores during practice, retention, and transfer for the Relatedness Support (RS), Relatedness Frustration (RF), and Control groups. Error bars indicate standard errors.

.304.

3.1.4. Transfer

Significant differences between groups were also found in the transfer test, F (2, 42) = 56.764, $p < .001$, $\eta_p^2 = 0.730$ (Fig. 2). Post hoc tests showed higher accuracy scores for the RS group than the RF, $p < .001$, and control, $p < .001$, groups. The control group also outperformed the RF group, $p = .005$.

3.2. Positive & negative affect

There were significant main effects of group for positive affect, F (2, 42) = 8.547, $p = .001$, $\eta_p^2 = 0.289$, and test, F (2, 84) = 5.518, $p = .006$, $\eta_p^2 = 0.116$ (Fig. 3). Interaction of test and group, F (4, 84) = 20.046, $p < .001$, $\eta_p^2 = 0.488$, was also found. Follow-up analyses for each group demonstrated a significant main effect of test for the RS group, F (2, 28) = 13.048, $p < .001$, $\eta_p^2 = 0.482$, with positive affect increasing from pre-test to after practice test, $t(14) = 6.393$, $p < .001$, as well as to before retention test, $t(14) = 2.705$, $p = .017$. A difference was also found between the after practice and before retention tests, $t(14) = 2.163$, $p = .048$. The main effect of test was also significant for the RF group, F (2, 28) = 25.681, $p < .001$, $\eta_p^2 = 0.647$. Positive affect was found to decrease from pre-test to after practice test, $t(14) = 11.415$, $p < .001$, as well as to before retention test, $t(14) = 5.139$, $p < .001$. A difference was not found between after practice and before retention tests, $t(14) = 0.560$, $p = .584$. Regarding the Control group the main effect of test was not significant, F (2, 28) = 2.275, $p = .121$, $\eta_p^2 = 0.140$. Significant correlations were not found between positive affect after pre-test and retention ($r = 0.153$, $p = .321$), or transfer ($r = 0.035$, $p = .820$) performance. Positive strong correlations between positive affect after practice and retention ($r = 0.572$, $p < .001$), and positive affect after practice and transfer ($r = 0.613$, $p < .001$) performance were found. Positive affect before retention also positively correlated with retention ($r = 0.487$, $p = .001$) and transfer ($r = 0.490$, $p = .001$) performance.

For negative affect, there were also significant main effects of group, F (2, 42) = 4.325, $p = .020$, $\eta_p^2 = 0.171$, test, F (2, 84) = 12.451, $p < .001$, $\eta_p^2 = 0.229$, and interaction of test and group, F (4, 84) = 31.418, $p < .001$, $\eta_p^2 = 0.599$ (see Fig. 3). A significant main effect of test, F (2, 28) = 17.708, $p < .001$, $\eta_p^2 = 0.558$ was found for the RS group, with negative affect decreasing from pre-test to after practice test, $t(14) = 17.3$, $p < .001$, and to before retention test, $t(14) = 4.350$, $p = .001$. A difference was also found between after practice and before retention tests, $t(14) = 2.703$, $p = .017$. The main effect of test was also significant for the RF group, F (2, 28) = 43.490, $p < .001$, $\eta_p^2 = 0.756$, with negative affect increasing from pre-test to after practice test, $t(14) = 9.504$, $p < .001$, but not to

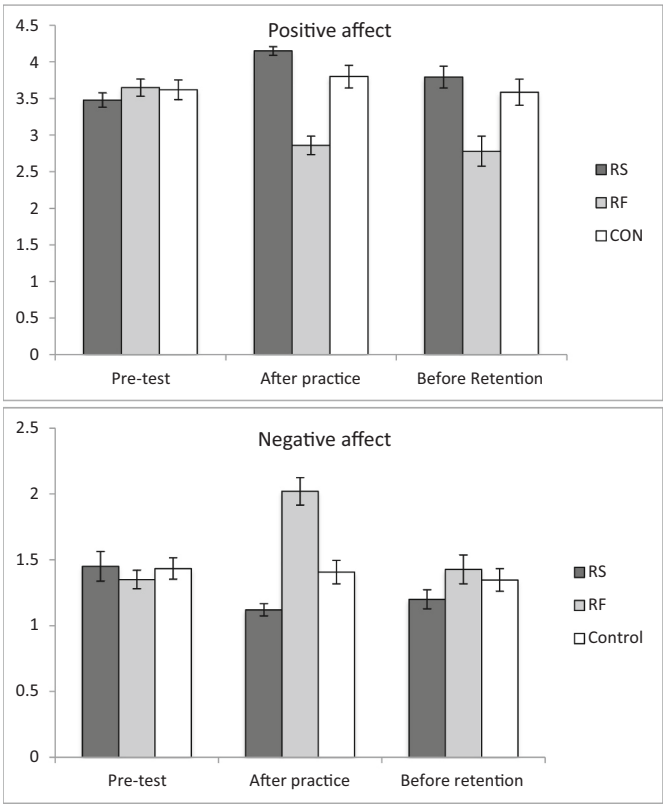

Fig. 3. Positive and negative affect scores after the pre-test and practice, and before the retention test for the Relatedness Support (RS), Relatedness Frustration (RF), and Control groups. Error bars indicate standard errors.

before retention test, $t(14) = 1.140$, $p = .274$. A difference was also found between after practice and before retention tests, $t(14) = 6.127$, $p < .001$. In the Control group the main effect of test was not significant, $F\ (2, 28) = 1.078$, $p = .354$, $\eta_p^2 = 0.140$. Significant correlations were not found between negative affect after pre-test and retention ($r = 0.013$, $p = .935$), or transfer ($r = 0.121$, $p = .435$) performance. Negative correlations between negative affect after practice and retention ($r = -533$, $p < .001$), and transfer ($r = -602$, $p < .001$) performance were found. Negative affect before retention did not correlate significantly with retention ($r = -195$, $p = .205$) or transfer ($r = -174$, $p = .259$) performance.

3.3. Self-efficacy

There were no significant main effects of group, $F\ (2, 42) = 1.821$, $p = .174$, $\eta_p^2 = 0.080$, or interaction of test and group, $F\ (4, 84) = 0.530$, $p = .714$, $\eta_p^2 = 0.025$, for self-efficacy (Fig. 4). Differences were found between tests, $F\ (2, 84) = 8.797$, $p < .001$, $\eta_p^2 = 0.173$. Self-efficacy increased from the pre-test to after practice ($p = .003$) and decreased from after practice to before retention ($p = .005$) in all groups. Significant correlations were not found between self-efficacy after pre-test and retention ($r = 0.246$, $p = .107$), or transfer ($r = 0.092$, $p = .553$) performance. A significant positive correlation was found between self-efficacy after practice and retention ($r = 0.321$, $p < .033$), but not for transfer ($r = 200$, $p < .193$) performance. Self-efficacy before retention also positively correlated with retention ($r = 0.320$, $p = .034$) but not for transfer ($r = 0.187$, $p = .235$) performance.

3.4. Intrinsic motivation inventory

For perceived relatedness, there were significant main effects of group, $F\ (2, 42) = 5.010$, $p = .011$, $\eta_p^2 = 0.193$, test, $F\ (2, 84) = 7.012$, $p = .002$, $\eta_p^2 = 0.143$, and interaction of test and group, $F\ (4, 84) = 19.512$, $p < .001$, $\eta_p^2 = 0.482$. Follow-up analysis for each group showed a significant main effect of test for the RS group, $F\ (2, 28) = 10.695$, $p < .001$, $\eta_p^2 = 0.433$, with perceived relatedness increasing from pre-test to after practice test, $t(14) = 5.067$, $p < .001$, and to before retention test, $t(14) = 3.005$, $p = .009$. A difference was not found between after practice and before retention tests, $t(14) = 0.323$, $p = .751$. In the RF group, the main effect of test was also significant, $F\ (2, 28) = 32.868$, $p < .001$, $\eta_p^2 = 0.701$. Perceived relatedness decreased from pre-test to after practice test, $t(14) = 11.602$, $p < .001$, and to before retention test, $t(14) = 5.967$, $p < .001$. A difference was not found between after practice and before retention tests, $t(14) = 0.126$, $p = .902$. In the Control group, the main effect of test was also significant, $F\ (2, 28) = 5.516$, $p = .010$, $\eta_p^2 = 0.283$. Perceived relatedness decreased from the pre-test to after practice, $t(14) = 2.567$, $p = .022$, and to before retention, $t(14) = 2.585$, $p = .022$. A difference was not found between after practice and before retention tests, $t(14) = 0.526$, $p = .607$. Perceived relatedness after pre-test was not correlated with retention ($r = 0.021$, $p = .891$), or transfer ($r = 0.039$, $p = .801$) performance. Significant positive correlations were found between relatedness after practice and retention ($r = 0.328$, $p = .030$), and transfer ($r = 361$, $p = .016$) performance. Perceived relatedness before retention also positively correlated with retention ($r = 0.476$, $p = .001$) and transfer ($r = 0.502$, $p = .001$) performance.

Similar results were found for enjoyment, where significant main effects of group, $F\ (2, 42) = 4.429$, $p = .018$, $\eta_p^2 = 0.174$, test, $F\ (2, 84) = 5.591$, $p = .005$, $\eta_p^2 = 0.117$, and interaction of test and group, $F\ (4, 84) = 3.392$, $p = .013$, $\eta_p^2 = 0.139$, were found. Follow-up analysis for the RS group showed a significant main effect of test, $F\ (2, 28) = 8.507$, $p = .001$, $\eta_p^2 = 0.378$; with levels of enjoyment increasing from pre-test to after practice test, $t(14) = 3.089$, $p = .008$, but not to before retention test, $t(14) = 0.702$, $p = .494$. Perceived enjoyment decreased from after practice to before retention test, $t(14) = 3.915$, $p = .002$. In the RF group, the main effect of test was also significant, $F\ (2, 28) = 4.285$, $p = .024$, $\eta_p^2 = 0.234$, with levels of enjoyment decreasing from pre-test to after practice test, $t(14) = 2.651$, $p = .019$, and to before retention test, $t(14) = 2.153$, $p = .049$. Perceived enjoyment did not differ from after practice to before retention test, $t(14) = 0.123$, $p = .904$. In the Control group, the main effect of test was not significant, $F\ (2, 28) = 2.248$, $p = .138$, $\eta_p^2 = 0.287$. Significant correlations were not found between enjoyment after pre-test and retention ($r = 0.144$, $p =$

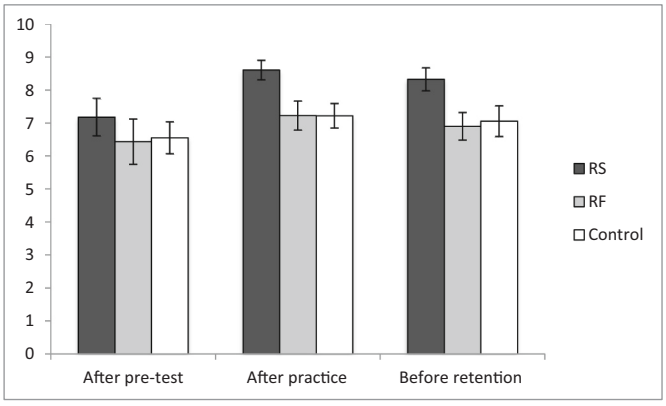

Fig. 4. Self-efficacy scores after the pre-test and practice, and before the retention test for the Relatedness Support (RS), Relatedness Frustration (RF), and Control groups. Error bars indicate standard errors.

.352), or transfer ($r = 0.059$, $p = .703$) performance. Significant correlation was not found between enjoyment after practice and retention ($r = 0.276$, $p = .070$), but the correlation was significant for transfer ($r = 394$, $p = .008$) performance. Enjoyment before retention was also not significantly correlated with retention ($r = 0.217$, $p = .158$), or transfer ($r = 0.271$, $p = .075$) performance.

For perceived competence, the main effect of group, $F(2, 42) = 2.442$, $p = .099$, $\eta_p^2 = 0.104$, and the interaction of test and group, $F(4, 84) = 1.689$, $p = .160$, $\eta_p^2 = 0.074$, were not significant. Differences were found between tests, $F(2, 84) = 5.621$, $p = .005$, $\eta_p^2 = 0.118$, with competence levels increasing from pre-test to after practice ($p = .021$) and to before retention ($p = .013$). Significant correlations were not found between perceived competence after pre-test and retention ($r = 0.094$, $p = .543$), or transfer ($r = 0.096$, $p = .537$) performance. A positive correlation was found between perceived competence after practice and retention ($r = 0.350$, $p = .020$), but not for transfer ($r = 0.244$, $p = .110$) performance. Perceived competence before retention positively correlated with performance on retention ($r = 0.436$, $p = .003$) and transfer ($r = 0.307$, $p = .043$).

For effort, the main effect of group, $F(2, 42) = 2.357$, $p = .107$, $\eta_p^2 = 0.101$, and test, $F(2, 84) = 1.520$, $p = .225$, $\eta_p^2 = 0.035$, were not significant. However, the interaction of test and group, $F(4, 84) = 2.858$, $p = .028$, $\eta_p^2 = 0.120$, was significant, but follow-up univariate ANOVAs (test) were not significant for any group. Perceived effort after pre-test was not correlated with retention ($r = 0.253$, $p = .098$), or transfer ($r = 0.226$, $p = .140$) performance. Significant positive correlations were found between effort after practice and retention ($r = 0.356$, $p = .018$), and transfer ($r = 425$, $p = .004$) performance. Perceived effort before retention also positively correlated with retention ($r = 0.325$, $p = .032$) and transfer ($r = 0.305$, $p = .044$) performance.

Results for perceived pressure/tension show the main effect of group was not significant, $F(2, 42) = 2.120$, $p = .133$, $\eta_p^2 = 0.092$, and no interaction of test and group, $F(4, 84) = 0.801$, $p = .528$, $\eta_p^2 = 0.037$, was observed. Differences were found between tests for perceived pressure, $F(2, 84) = 4.917$, $p = .010$, $\eta_p^2 = 0.105$, with the groups decreasing in perceived pressure from the pre-test to after practice ($p = .003$) and from after practice ($p = .012$) to before retention. Significant correlations were not found between pressure/tension after pre-test and retention ($r = 0.143$, $p = .353$), or transfer ($r = 0.087$, $p = .573$) performance. Significant correlations were also not found between pressure/tension after practice and retention ($r = 0.044$, $p = .778$), or transfer ($r = 009$, $p = .954$) performance. Perceived pressure before retention also did not correlate with retention ($r =$. -133, $p = .391$) or transfer ($r =$. -135, $p = .386$) performance.

For perceived choice, the main effect of group was marginally non-significant, $F(2, 42) = 3.055$, $p = .058$, $\eta_p^2 = 0.104$. Differences were found between tests, $F(2, 84) = 5.417$, $p = .006$, $\eta_p^2 = 0.114$. Interaction of test and group, $F(4, 84) = 2.598$, $p = .042$, $\eta_p^2 = 0.110$, was also observed. Follow-up analysis showed the main effect of test in the RS group was not significant, $F(2, 28) = 0.483$, $p =$

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 Relatedness Support (RS), Relatedness Frustration (RF), and Control groups.

IMI Subscales	Groups		
	RS		
	Pre-test	After Practice	Before Retention
Enjoyment	5.55 (0.78)	5.93 (0.70)	5.46 (0.87)
Competence	3.93 (0.99)	4.86 (0.83)	4.91 (0.74)
Effort	5.73 (1.07)	6.21 (0.66)	5.75 (0.85)
Tension	2.16 (1.21)	2.21 (1.09)	1.78 (0.87)
Choice	6.38 (0.63)	6.51 (0.47)	6.38 (0.79)
Value	5.70 (0.99)	6.10 (0.83)	5.48 (1.02)
Relatedness	5.65 (0.61)	6.16 (0.32)	6.13 (0.29)
	RF		
	Pre-test	After Practice	Before Retention
Enjoyment	5.46 (0.84)	4.65 (1.31)	4.61 (1.48)
Competence	3.76 (1.53)	3.75 (1.29)	3.80 (1.36)
Effort	5.73 (1.07)	5.16 (1.71)	5.15 (1.66)
Tension	2.70 (1.40)	2.23 (1.04)	2.16 (1.09)
Choice	6.15 (0.88)	5.66 (1.25)	5.46 (1.11)
Value	5.03 (1.35)	4.38 (1.63)	3.81 (1.48)
Relatedness	6.05 (0.52)	5.21 (0.50)	5.23 (0.24)
	Control		
	Pre-test	After Practice	Before Retention
Enjoyment	5.83 (0.81)	5.75 (0.64)	5.41 (0.74)
Competence	3.80 (1.11)	4.23 (1.29)	4.43 (1.38)
Effort	6.10 (0.87)	6.21 (0.78)	6.08 (1.02)
Tension	2.88 (1.38)	2.98 (0.80)	2.41 (0.95)
Choice	6.33 (0.75)	5.83 (0.75)	6.00 (0.75)
Value	5.91 (1.02)	5.98 (0.96)	5.38 (1.42)
Relatedness	6.12 (0.58)	5.76 (0.83)	5.80 (0.56)

.622, $\eta_p^2 = 0.033$. In the RF group, the main effect of test was significant, $F(2, 28) = 7.868$, $p = .002$, $\eta_p^2 = 0.360$. Perceived choice decreased from pre-test to after practice test, $t(14) = 2.761$, $p = .015$, and to before retention test, $t(14) = 3.544$, $p = .003$. Perceived choice did not differ from after practice to before retention test, $t(14) = 1.233$, $p = .238$. In the Control group, the main effect of test was not significant, $F(2, 28) = 2.408$, $p = .108$, $\eta_p^2 = 0.147$. Perceived choice after pre-test was not correlated with performance on retention ($r = 0.190$, $p = .216$) or transfer ($r = 0.147$, $p = .341$). Significant correlation was also not found between perceived choice after practice and retention performance ($r = 0.241$, $p = .115$), but the correlation was positively significant for transfer ($r = 0.410$, $p = .006$). Perceived choice before retention also positively correlated with performance on retention ($r = 0.303$, $p = .046$) and transfer ($r = 0.333$, $p = .027$).

Lastly, there were significant main effects of group, $F(2, 42) = 7.545$, $p = .002$, $\eta_p^2 = 0.264$, test, $F(2, 84) = 13.569$, $p < .001$, $\eta_p^2 = 0.244$, and interaction of test and group, $F(4, 84) = 3.160$, $p = .018$, $\eta_p^2 = 0.131$, in the value subscale. In the RS group, the main effect of test was significant, $F(2, 28) = 5.434$, $p = .010$, $\eta_p^2 = 0.280$. Perceived value increased from pre-test to after practice test, $t(14) = 3.292$, $p = .005$, but not to before retention test, $t(14) = 1.055$, $p = .309$. Perceived value also differed from after practice to before retention test, $t(14) = 2.728$, $p = .016$. In the RF group, the main effect of test was also significant, $F(2, 28) = 7.964$, $p = .002$, $\eta_p^2 = 0.363$. Perceived value decreased from pre-test to after practice test, $t(14) = 2.434$, $p = .029$, and to before retention test, $t(14) = 4.172$, $p = .001$. Perceived value did not differ from after practice to before retention test, $t(14) = 1.616$, $p = .128$. In the Control group, the main effect of test was also significant, $F(2, 28) = 4.821$, $p = .016$, $\eta_p^2 = 0.256$. Perceived value did not differ from pre-test to after practice test, $t(14) = 0.487$, $p = .634$, but decreased to before retention test, $t(14) = 2.221$, $p = .043$. Perceived value also decreased from after practice to before retention test, $t(14) = 2.487$, $p = .026$. Significant correlations were not found between perceived value after pre-test and retention ($r = 0.226$, $p = .140$), and transfer ($r = 0.262$, $p = .086$) performance. A positive correlation was found between task value after practice and retention performance ($r = 0.386$, $p = .010$), and transfer ($r = 0.456$, $p = .002$). Perceived value before retention also positively correlated with performance on retention ($r = 0.329$, $p = .029$) and transfer ($r = 0.342$, $p = .023$).

Table 1 shows the means and standard deviations for all IMI subscales during pre-test, after practice, and before retention.

4. Discussion

The present experiment aimed to verify the effects of the basic psychological need for relatedness on the performance and learning of a motor task in adolescents; potential underlying mechanisms were also investigated. The results show that instructions emphasizing recognition and interest in the learners' experiences lead to better performance and learning relative to instructions that do not fully support the need for relatedness in this population. Participants practicing in the relatedness frustration condition had, in addition, lower performance scores on the transfer test relative to the control group, demonstrating the negative impact of needs thwarting on motor learning. These findings are in line with previous motor learning experiments in young adults (Chiviacowsky et al., 2019; Gonzalez & Chiviacowsky, 2018), as well as in older adults (Silva & Chiviacowsky, 2020), showing the effects of relatedness on motor learning are robust, while also generalizing to distinct populations.

The findings also showed different levels of positive and negative affect between groups, with inferior results in both measures for participants in the relatedness frustration condition, and significant correlations between affective levels, and retention and transfer performances. The sense of belonging or the satisfaction of the need for relatedness has been associated with positive affect, while threat and frustration is associated with negative affect in adolescents (Allen, Hauser, Eickholt, Bell, & O'Connor, 1994; Niemiec et al., 2006). Positive affect causes an increase in 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). Dopamine activity helps the consolidation and coding of long-term memory (Di Domenico & Ryan, 2017; Murty & Dickerson, 2016; Sugawara, Tanaka, Okazaki, Watanabe, & Sadato, 2012), thus it helps with learning. Evidence of relatedness influencing motor learners' levels of positive affect were observed in Gonzalez and Chiviacowsky's (2018) experiment, while changes in dopamine activity, observed through measures of blinking rate during practice, were observed in Chiviacowsky et al.'s (2019) experiment.

Participants in the distinct groups did not report different levels of self-efficacy, measured after practice or before retention, but significant positive correlations were found between self-efficacy after practice and before retention, with performance in retention. Self-efficacy, the confidence or the feeling of an individual of being able to perform an action that will produce a determined result in a specific situation (Bandura, 1977), has been found to be a predictor of both 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). The group receiving instructions emphasizing interest and care in the participant's experience showed higher intrinsic motivation, with increased perceived levels of enjoyment, value, choice, and relatedness relative to the group in which the relatedness need was frustrated. Such results are in line with relatedness studies including adults in motor learning (Gonzalez & Chiviacowsky, 2018) and with adolescents in other domains, where their perceptions of a teacher-student relationship were positively associated with perceived competence and autonomy (e.g., Bakadorova & Raufelder, 2018). The sense of belonging and the satisfaction of the need for relatedness have already been observed to predict perceptions of self-efficacy and intrinsic motivation in adolescents (Freeman, Anderman, & Jensen, 2007; Kim & Keller, 2008; Usher & Pajares, 2009; Zumbrunn, McKim, Buhs, & Hawley, 2014). The OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016) proposes that two key motivational factors — enhancing learners' expectancies for successful performance and supporting their need for autonomy — can contribute to motor learning by strengthening the coupling of goals to actions, readying the motor system for task execution, and helping to consolidate memories. While supporting the learners' need for relatedness, instructions emphasizing care, importance, and interest in the participant's experience may act similarly, thus facilitating the acquisition

of motor skills.

In conclusion, the present experiment provides the first evidence that the need for relatedness affects underlying mechanisms of affect and motivation involved in adolescents' motor performance and learning. Specifically, instructions emphasizing recognition and interest in the experience of adolescents results in greater intrinsic motivation, higher positive and lower negative affect rates, and better motor skill performance and learning in this population relative to instructions that emphasize disinterest in the participant as a person or that do not fully support social relatedness. Our study was limited to investigate social relatedness effects in a simple aiming task in adolescents. Future research could investigate the generalization of the results found in other kinds of tasks, practice contexts, and populations (e.g., children, those with disabilities, or individuals with distinct personality traits). Another limitation of the present study was its use of the same experimenter for both the practice and test phases. While we do acknowledge that it may be difficult if personnel are limited, utilizing a different experimenter for the testing or practice phase would be a preferable arrangement. Other motivational measures, such as persistence or willingness to continue practicing the task or the use of post-failure measures allowing the observation of participant's capacity to cope with errors (e.g., Chiviacowsky & Drews, 2014), could reveal differences in performance and learning between groups that were not captured in the present study. The effects of social relatedness provided by peers, or in contexts that typically promote cooperation or competition (Johnson & Johnson, 1974), could also be fruitful avenues for subsequent research.

Declaration of Competing Interest

None.

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