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Psychological and hormonal effects of socio-emotional learning in adolescents: a randomized controlled trial

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Socio-emotional learning (SEL) is thought to increase children and youth's social competencies such as empathy, however it has not been widely integrated in educational settings. This may be due to a lack of randomized-controlled trial (RCT) designs and objective and quantitative measurements, including of its neurobiological underpinnings, particularly in adolescence. This study examined the effect of a 1-week SEL intervention, and of a group-bonding task within it, on salivary oxytocin levels, and on the Multifaceted Empathy Test, using an RCT design and a repeated measures between subjects ANOVA, in 88 adolescents (35 female and 53 male). We found that salivary oxytocin was increased by performing the group-bonding task ($p = 0.007$, $\eta^2 p = 0.089$), but the 1-week intervention as whole did not augment this increase. The intervention increased emotional empathy, at a statistical trend level, in females. Lastly, an emotional empathy increase (from the first time to second time performing the group-bonding task) was positively correlated with an oxytocin increase ($r = 0.235$, $p = 0.033$), regardless of intervention. These findings point to a positive impact of SEL on emotional empathy, and of group-bonding tasks on endogenous oxytocin release, albeit preliminarily; with further replicatory research warranted.

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Introduction

A healthy social and emotional development during childhood and young age is key for the promotion of well-being in society at large. The learning of social emotional skills while at school has a decisive role in forming ethical and socially well adapted citizens (Greenberg et al. 2003; Weissberg and O'Brien, 2004), and especially important for those who will engage in leadership roles (Greenberg et al. 2003). As such, the training of servant leadership (i.e. where the fulfilment of followers is prioritized by leaders) is invariably targeted to provide students with social-emotional learning (SEL) (Grothaus, 2004). They have the potential to be delivered in a highly impactful, far-reaching manner, regardless of participant's social strata, if done efficiently through universal programmes in schools (Durlak et al. 2011). However, for such massive implementation, it is essential to provide political decision-makers with evidence of the efficacy of servant leadership SEL intervention.

In the last few decades, there has been a growing interest in servant leadership research, but the majority of studies have been in management and workplace contexts (Canavesi and Minelli, 2022; Eva et al. 2019). Compelling research on servant leadership in education, during school years, is scarce. Regarding research design, a systematic review on servant leadership found that, since 1998, only three studies used experimental methodology (Eva et al. 2019), with none using a random controlled trial (RCT) or a within-subjects design. Several socio-emotional characteristics of a servant leader have been identified, and are thought to be enhanced through learning and practice, including listening and self-awareness, and, centrally, cognitive and emotional empathy skills (Spears, 2010). Indeed, increased empathy (albeit vaguely and qualitatively defined) is an outcome of servant leadership training but there is insufficient evidence – only two studies and only qualitative - in adolescence (Chan, 2018; Eva et al. 2019; Grothaus, 2004). Research is vaster on effects of non-leadership related SEL interventions in youth, comparing psychological questionnaires or tasks assessments between a pre-intervention and a post-intervention phase, with an RCT design. Two meta-analyses in youth found significantly positive but small effects, of $d = 0.15$ to $d = 0.22$ (Goldberg et al. 2019; January et al. 2011), on social and emotional adjustment. Nevertheless, not all interventions produce positive results, which is likely due to an incomplete evaluation model among other factors (Wigelsworth et al. 2016). Also, rarely are behavioural tasks employed. These would capture implicit and sub-conscious skills and allow for more objective and sensitive assessments of behaviour, instead of questionnaires which depend on the subjects' subjective appraisal of their own behaviour and are subject to a confounding effect of social desirability. Physiological measurements, such as endogenous hormonal levels, have also not been employed to study SEL in the healthy population - to our knowledge – even though they may theoretically reveal even larger (hidden) effects than the above pure psychological measurements, and are essential for the understanding of the biological mechanisms underlying SEL. In specific, endogenous oxytocin levels (which we measure in the present study) have been investigated as outcomes of socio-emotional interventions in pathological conditions such as in Autism Spectrum Disorder, albeit employing inconclusive statistical power (Corbett et al. 2011); in psychosis, showing increased oxytocin responses (Speck et al. 2019); and in other disorders as reviewed elsewhere (Torres et al. 2018). Due to these knowledge gaps, the underlying neurobiological mechanisms of any potential effects of such interventions are still unknown.

Empathy, in particular, has emerged as a socio-cognitive/emotional process that responds to SEL interventions, which makes sense as the efficacy of social interactions should depend on the ability to detect and infer emotional and cognitive processes in others (Dvash and Shamay-Tsoory, 2014; Völlm et al. 2006). While emotional empathy is the ability to share and react to the emotional experiences of others, cognitive empathy is the understanding of others' mental states, a.k.a. Theory of Mind (Baldwin, 1906). A metanalysis of 18 RCT studies (van Berkhout and Malouff, 2015) has revealed significantly positive effects in adults, as well as in the 3 of 4 studies in youths. In the first study, in children with Autism Spectrum Disorder (Begeer et al. 2011) an improvement was reported in conceptual ToM after a 16-week social skills training. In the second study, in children with behavioural disorders (Dadds et al. 2012), an RCT reported improvements in affective empathy after a 6-month emotion-recognition-training. Finally, in the third study with aggressive adolescent females in a residential treatment centre (Pecukonis, 1990), increased emotional but not cognitive empathy was found after four training sessions of emotional/cognitive empathy training. However, there is, to our knowledge, only one RCT of SEL in normative population youths (Schonert-Reichl et al. 2015b), which showed that elementary school children to improve in cognitive and emotional empathy (empathic concern and perspective-taking) after 12 lessons of mindfulness-based SEL.

On a, so far, empirically separated stream of research, the neurophysiological basis of socioemotional skills has advanced in the last few decades. The hypothalamic-released neuropeptide oxytocin is now widely believed to play a central role in a range of social cognition skills, in non-human animal and human subject research from correlational as well as RCT studies (Jones et al. 2017), as has been reviewed elsewhere in particular for youth (Torres et al. 2018). There is evidence that intranasally administered oxytocin improves trust between humans (Kosfeld et al. 2005), the use of social relationships to manage stress (Feldman et al. 2016), overall mental health (Neumann and Landgraf, 2012), maintaining eye-contact (Guastella et al. 2008), total empathy (Feldman et al. 2016; Meyer-Lindenberg et al. 2011), cognitive empathy (Domes et al. 2007), and emotional empathy (Geng et al. 2018; Le et al. 2020). Further evidence supporting oxytocin as a neuromodulator of empathy, the experience of practicing empathy has been found to increase oxytocin levels 47%, this response being stronger in women than in men (Barraza and Zak, 2009). An increased release of oxytocin has also been associated with positive social interactions (such as eye gaze, physical contact and touch) (Bellosta-Batalla et al. 2020a; Guastella et al. 2008). It has also been shown that this oxytocin increase may not hold constant with the continuation of social group activity, and in fact, may decrease, such as after choir group singing (with no change after solo singing) (Schladt et al. 2017) or familiarization-habituation in a social experimental task (Tops et al. 2013). As such, oxytocin is thought to be involved in the habituation to social challenge and novelty, being increased by social support (Grewen et al. 2005).

In terms of the impact of educational interventions, a study using, in university psychology students, a mindfulness (a.k.a. full awareness) and/or compassion-based intervention has increased salivary oxytocin levels both after 8 sessions (Bellosta-Batalla et al. 2020b) and in just one 1.5 h session (Bellosta-Batalla et al. 2020a); as well as self-reported cognitive empathy for the former study (Bellosta-Batalla et al. 2020b). In a sample of female university students, oxytocin increased after a 15-minute gossip conversation (irrespective of empathy) as compared to an emotional non-gossip conversation and to a neutral conversation (with no difference between the latter two conversations) (Brondino et al. 2017). Albeit not in an educational setting, in a young adults study, watching an empathy-inducing video (of a father talking about his gravely ill child), has shown an increase in salivary

oxytocin (both immediately and 20-minutes post-video); with women (vs. men) reporting a higher increase in the empathy-related response (Procyshyn et al. 2020). Despite such informative findings in the association of oxytocin to empathy in adults, the research in children and adolescents is still scarce. In the adolescent population with conduct problems and callous-unemotional traits, salivary oxytocin levels were negatively correlated with the severity of conduct problems and, expectedly, those with high conduct problems and low oxytocin levels were more likely to have high callous-unemotional traits (Levy et al. 2015). In maltreated school children, salivary levels increased 112% to 165%. after group drumming intervention sessions (Yuhi et al. 2017).

The above evidence has clearly advanced the characterization of the neurobiological mechanisms underlying empathy, namely in clinical and workplace settings, but – as said – is still scarce in children and adolescent educational settings. The latter however, is essential to objectively and quantitatively certify the efficacy of SEL (including servant leadership) training, which can be a first step to its dissemination throughout educational systems. For example, the 1-week long Ubuntu Leaders Academy (ULA) training, a servant leadership-focused SEL programme which aims to develop empathy, self-knowledge, self-confidence, resilience, and service, has been designed in Instituto Padre António Vieira, Portugal, in 2010, following the Ubuntu methodology, and has since grown to 59 countries (Ubuntu Leaders Academy, 2024). This intervention carries a huge potential of empowering children and young people to serve their local communities as leaders and increasing well-being and pro-social behaviour in the general population at large, once integrated in the public and compulsory school curricula.

In the current study, we aimed to characterize the impact, at the hormonal (i.e., salivary oxytocin), and psychological (i.e., performance-based empathy, as quantitatively measured with the Multifaceted Empathy Test, MET) levels, of a servant leadership-focused SEL intervention programme, and – in specific - one of its team-building activities (the Web Wool Task); with possible effects of also examined. Our hypotheses were:

H1) The performance of the Web Wool Task would increase levels of salivary oxytocin. This would be reflected in a main or a time-specific effect of the Web-task.

H2) The above oxytocin increase would be higher after ULA training, i.e., in ULA participants compared to non-participants, at the last day of the intervention compared with the first day. This would be reflected in a group by Web-task interaction.

H3) Undergoing the ULA training would increase emotional and cognitive empathy. This would be reflected in a group by intervention interaction.

H4) The above increases in oxytocin and in empathy would be associated. This would be reflected in a positive linear correlation.

Methods

Design and participants. We used a unblinded RCT experimental design in a naturalistic setting. Four groups of adolescents (2 control: 17 and 17 in size; 2 ULA: 30 and 24 in size) totalling 88 participants, and corresponding to four school classes of the same school each, participated in the study. For all analyses, these were grouped in control ($N = 34$) and ULA ($N = 54$) groups and had unbalanced age distributions ($M = 14.65$, SD = 0.56 for ULA; $M = 14.0$, SD = 0.90 in control; $t = 4.36$ (df = 86), $p < 001$) and balanced female:male ratio (12:22 in ULA, and 23:31 in control; χ^2: 0.467 (df = 1); $p = 0.496$) (Table 1). Participants were recruited at *Agrupamento de Escolas À Beira Douro* schools, and the sessions took place at *Escola Básica e secundária à beira Douro* school. The two intervention groups had been recruited and scheduled to undergo the ULA training week before and regardless of the present study being designed. The two control groups had been randomly selected to undergo the ULA week at a posterior date to the present study data collection, and were thus used as controls to the abovementioned intervention groups. Although the training was the same for all ULA groups, one ULA and one control group were taught by the same team of three hosts; which was different from the host team of the other ULA and control groups. This study's design was not pre-registered. Given the high naturalistic nature of the study's sampling, inclusion criteria were attendance to the said schools and school year, native Portuguese speaking, and parents/guardian's authorization for their adolescent children to undergo the ULA training.

Table 1 Sample's demographic characteristics.

	N	N total	Age	Sex (Female:Male)
Control 1	17	34	$M = 14.0$,	23:31
Control 2	17		SD = 0.90	
ULA 1	30	54	$M = 14.65$,	12:22
ULA 2	24		SD = 0.56	
Control vs ULA	-	-	$t = 4.36$ (df = 86), $p < 001$	χ^2: 0.467 (df = 1); $p = 0.496$

ULA Ubuntu Leadership Academy, *SD* standard deviation, *df* degrees of freedom.
N = number of subjects.

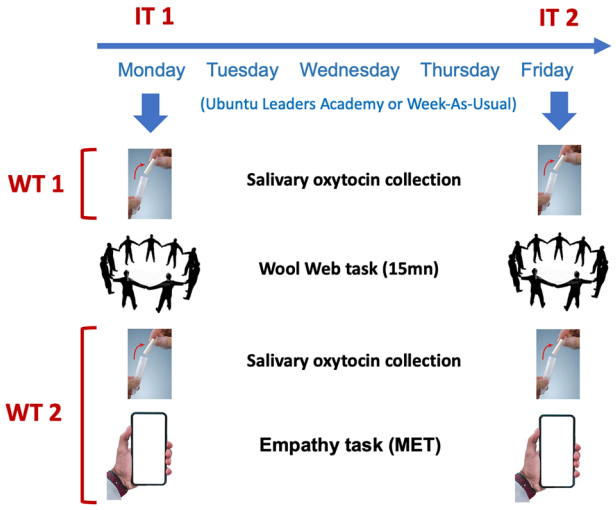

Fig. 1 Diagram of data collection events and timings.

The ULA intervention week (five day-programme) consists of inspiring storytelling and real-life stories, relational dynamic role-play, and videos that stimulate individual and group reflection on socio-emotional issues – aiming at the development of five social skills: empathy, self-knowledge, self-confidence, resilience, and service. The controls participants in the study had a 'week-as-usual' with social interactions within each group which typically occurs in a school week, with no participation in any of the ULA training activities, except for the Wool Web Task (Fig. 1, see next section).

Experimental procedure. All participants engaged in the Wool Web Task as the first activity of the first day of the ULA/control week. This activity was then repeated at the same time on the last day of the week. The Wool Web Task (lasting 15 mn) consisted of the whole group standing in a circle. One of the subjects was given a yarn of wool and was told to wrap the end of the yarn to

their finger and then pass the rest of the yarn to another participant of their own spontaneous choice (except those immediately to their left or right), while saying the recipients' name out loud. The receiving participant would repeat the task attaching part of the string of yarn to their finger. As more and more participants are thrown the yarn a web is created in the circle. Instructions were: *"1. Dá uma volta com a ponta do novelo ao teu dedo; 2. Diz em voz alta o nome da pessoa a quem vais atirar o novelo (não deve ser a pessoa imediatamente ao teu lado); 3. Atira o novelo a essa pessoa."* (English translation1. Please turn the yarn once around your finger; 2. Say the name of the person you are going to throw the yarn to out loud (it should not be the person standing immediately next to you); 3. Throw the yarn to that person).

Before and after each Wool Web Task activity, participants provided a saliva sample for oxytocin measurement, into a Salivette® vial. As per the Salivette® instructions of use, all participants confirmed they had not eaten or brushed teeth 30 minutes prior, and then put the vial's sponge in their mouths and allowed the saliva to soak into it for at least 2 min before spitting it back into the vial. After this, all vials were immediately frozen at −20 °C until oxytocin measurement, which took place in approximately months. After the second saliva collection, for each day, participants filled the questionnaire Multifaceted Empathy Test (Dziobek et al. 2008a) in Qualtrics® on their smartphones. After the saliva sample of the first day (only), they filled the Empathy Quotient – short version (Rodrigues et al. 2011), and the Interpersonal Reactivity Index (Limpo et al. 2010).

Psychological instruments. The MET measures cognitive and emotional empathy simultaneously as the first multidimensional empathy test (Dziobek et al. 2008b). It consists of emotionally charged photographs, and participants are prompted to: (1) select the emotional state of each individual pictured from a choice of four options- as a way to gauge cognitive empathy; and (2) assess their own emotional response to the images on a scale from one to nine- as a way to gauge emotional empathy. It has been shown to be useful in a wide range of scientific research, helping answer questions on the role of neurochemicals and their interactions (Duesenberg et al. 2016; Hurlemann et al. 2010; Nowacki et al. 2020), and inter-individual differences in empathy (Kuypers, 2017; Ze et al. 2014). In addition to its unique multidimensional aspect, the MET addresses several limitations of earlier empathy measurement tools. First, MET is a task rather than a self-report questionnaire on empathy, and thus, being more sensitive and objective, allows for more generalizable assessments than questionnaires (Guhn et al. 2020). Second, MET stimuli are photo-realistic, and indicative of real-world behaviour, thus of superior ecological validity (Friedman and Banich, 2019). Third, the MET assessed participants' emotional reaction to the person within the images as opposed to participant reaction to the overall image, including context and background. We used a previously translated and back-translated Portuguese version of the MET which has been validated (unpublished).

The IRI consists of 24 questions, on a 5-point Likert-type scale, that was developed to measure empathy using four 6-item subscales: Perspective Taking, Fantasy, Empathic Concern, and Personal Distress). The perspective taking scale (PT) correlates highly with the cognitive component of empathy whereas the empathetic concern scale (EC) and personal distress scale (PD) correlate highly with the affective (emotional) component of empathy (De Corte et al. 2007). The EQ (short-form) is a 22-item questionnaire, scored on a four-point Likert scale, that reflects on an individual's ability to recognize, understand, manage, and navigate their own emotions and the emotions of others. It measures empathy using four subscales: Cognitive Empathy, Emotional Reactivity, Social Abilities and Empathic Difficulties. Both the Empathy Quotient – short version (Rodrigues et al. 2011) and the Interpersonal Reactivity Index (Limpo et al. 2010) validation in the European Portuguese population have been published elsewhere".

Oxytocin measurement. Oxytocin measurement was performed at RIAgnosis lab in Munich, Germany (following methodology published elsewhere (Jurek and Neumann, 2018)). Saliva samples were stored at −20 °C until extraction using LiChroprep Si60 heat-activated at 700 °C for 5 h. 20 mg of LiChroprep Si60 in 1 ml of distilled water was added to each sample, which was then mixed for 30 min, washed twice with distilled water and 0.01 N HCI and then eluded with 60% acetone. After evaporation in a SpeedVac, samples were kept at −20 °C. The extraction recovery range was 85–90%. The data was not corrected for recovery. Then, 50 µl of assay buffer was added to the extract to assay OXT using a specific and sensitive radioimmunoassay (RIAgnosis). Briefly, 50 µl of a polyclonal antibody was added to each sample. Following a 1-h preincubation period, 10 µl of the 125I-labelled tracer was added to the sample, which was then incubated for 3 days at 4 °C. Unbound radioactivity was precipitated by activated charcoal. Under these experimental conditions, an average of 50% of total counts is bound with <5% non-specific binding. The detection limit is in the 0.1–0.5 pg/sample range, depending on the age of the tracer, with typical displacements of 20–25% at 2 pg, 60–70% at 8 pg and 90% at 32 pg of standard neuropeptide. Cross-reactivity to structurally related peptides including arginine vasopressin, the hexaring of oxytocin and its terminal tripeptide were <0.7%.

Statistical analysis. In a repeated measures ANOVA, using SPSS v20, effects of the between-subjects variable Group (ULA, control), a within-subject temporal variable Intervention (IT1, IT2; for pre- and post- ULA week duration, respectively) and a within-subject temporal variable Web-task (WT1, WT2; for pre- and post-Web-task performance, respectively) on the levels of salivary oxytocin were estimated. Another repeated measures ANOVA of MET (emotional and cognitive empathy) was used to estimate effects of the between-subjects variable Group (ULA, control) with the within-subject temporal variable Intervention (IT1-WT2, IT2-WT2). A post-hoc correlation between an intervention-induced change in emotional empathy and a change in oxytocin levels, in the same time points (IT1-WT2 vs. IT2-WT2), and its moderation by intervention group was also tested with a multiple regression. Moderations of the oxytocin model by baseline/trait MET, IRI and EQ were also examined. Associations of sex and age with the above independent (see above) and dependent variables were tested with χ^2 and t-tests respectively, to ascertain its possible role as an extraneous or confounding variable. Results were considered statistically significant when p-value < 0.05.

Results

Oxytocin levels. There was an interaction of intervention and Web-task ($F(1, 74) = 6.281$, $p = 0.014$, $\eta^2p = 0.078$, Fig. 2) on oxytocin levels. Post-hoc comparisons, per intervention time-point, revealed a significant effect of Web-task only before the ULA intervention (i.e. time IT1; $F(1, 78) = 7.642$, $p = 0.007$, $\eta^2p = 0.089$), such that there was an increase in oxytocin levels after the Web-task compared to before the start of the task (i.e. in WT2 vs. WT1); and not within IT2 ($F(1, 78) = 7.642$, $p = 0.180$). Moderation by empathy measures (IRI, EQ or MET) did not substantially or significantly change the above results.

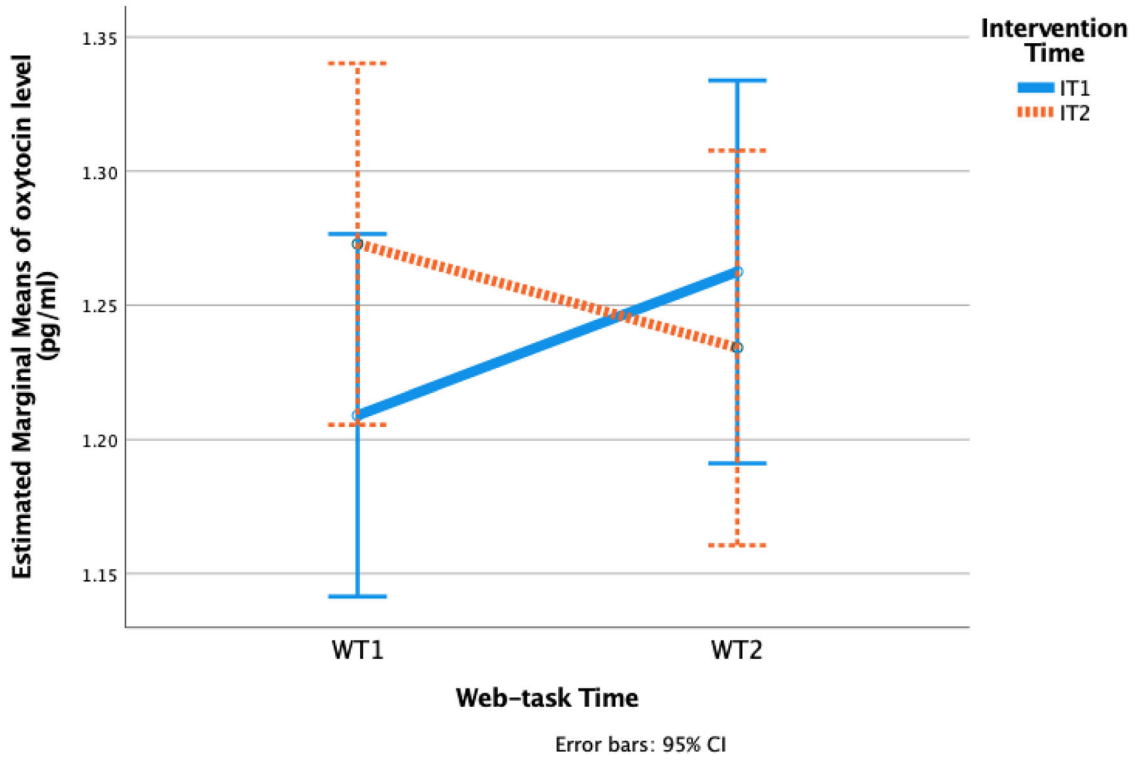

Fig. 2 Plot of oxytocin salivary levels as a function of intervention and Web-task, for both groups combined.

Sex ($F(1, 74) = 0.57$, $p = 0.453$) and age ($F(1, 86) = 0.421$, $p = 0.518$) were not associated with salivary oxytocin levels. There was no main effect of group ($F(1, 74) = 1.620$, $p = 0.207$), nor a group by intervention interaction ($F(1, 74) = 0.111$, $p = 0.741$), nor of a group by Web-task interaction ($F(1, 74) = 0.256$, $p = 0.614$) on oxytocin levels, nor a 3-way interaction between these 3 variables ($F(1, 74) = 0.004$, $p = 0.948$).

Empathy task. There was a significant main effect of group on the emotional dimension of the MET ($F(1, 86) = 4.543$, $p = 0.036$, $\eta^2p = 0.05$, Fig. 3). The corresponding plots suggest this was driven by a IT1-WT2 to IT2-WT2 increase in emotional empathy in the ULA group (although not statistically significant within this group, $F(1, 53) = 2.032$, $p = 0.160$, $\eta^2p = 0.037$), and a non-increase in the control group. Nevertheless, a group by intervention interaction was not statistically significant ($F(1, 86) = 1.42$; $p = 0.237$; $\eta^2p = 0.02$).

Even though MET emotional empathy did not significantly differ between sex groups in either time point (IT1-WT2: $F(1, 86) = 0.389$, $p = 0.535$, $\eta^2p = 0.004$; IT2-WT2: $F(1.86) = 0.13$, $p = 0.08$; $\eta^2p = 0.035$), when sex was added to the model, it significantly modulated the above main effect of group via a sex by group interaction ($F(1, 84) = 13.151$, $p < 0.001$, $\eta^2p = 0.135$), such that the above-mentioned higher emotional empathy in the ULA (vs. control) group was significant in females ($F(1, 51) = 16.457$, $p < 0.001$, $\eta^2p = 0.24$; Fig. 3), but not males ($F(1, 33) = 1.992$, $p < 0.168$, $\eta^2p = 0.06$, Fig. 3). (However, even in females alone, a group by intervention interaction was not statistically significant [$F(1, 51) = 1.328$, $p = 0.255$; $\eta^2p = 0.025$]). A 3-way interaction was not statistically significant (data not presented).

As for MET cognitive empathy, and unlike for emotional empathy, there was a main effect of sex ($F(1, 86) = 11.272$, $p = 0.001$), such that female participants showed higher scores on the cognitive dimension of MET, compared to males, irrespective of time point. (However, even with the inclusion of sex in the model estimating the above effect of group, there were no statistically significant effects on cognitive empathy [data not presented]).

Association between oxytocin and the empathy task. Given the above results, we tested if the found intervention-induced increase in emotional empathy was correlated with a change in oxytocin levels between the same time points (IT1-WT2 vs. IT2-WT2). This was confirmed by a positive relationship ($N = 83$, $r = 0.235$, $p = 0.033$, CI 95% [0.020, 0.429], 2-tailed; Fig. 4), irrespective of group. We further explored this correlation in each group, finding that it was not statistically significant in either alone but showed a suggestive trend of $p = 0.066$, and higher effect size, in the ULA group ($N = 52$, $r = 0.256$, $p = 0.066$) rather than in the control group ($N = 31$, $r = 0.147$, $p = 0.431$). A moderation of this correlation by group was not statistically significant (data not shown).

Discussion

We have conducted an RTC of a 1-week servant leadership-focused SEL training in adolescents in a secondary school setting, for which we measured changes in the size of the difference in emotional and cognitive empathy and salivary oxytocin induced by the Wool Web team building task. Our findings suggest the following interpretation of our hypotheses.

H1 - Salivary oxytocin increased after an Ubuntu Leader Academy training task activity (the Wool Web Task). Our hypothesis that the performance of the bonding-inducing Wool Web Task - which is usually part of the ULA training - would increase levels of salivary oxytocin, regardless of ULA training, was supported by the present data. We found a highly statistically significant and large effect of the Wool Web Task performance on oxytocin salivary levels, whereby it explained 9% of the variance, left unexplained by other factors. This was irrespective of sex or

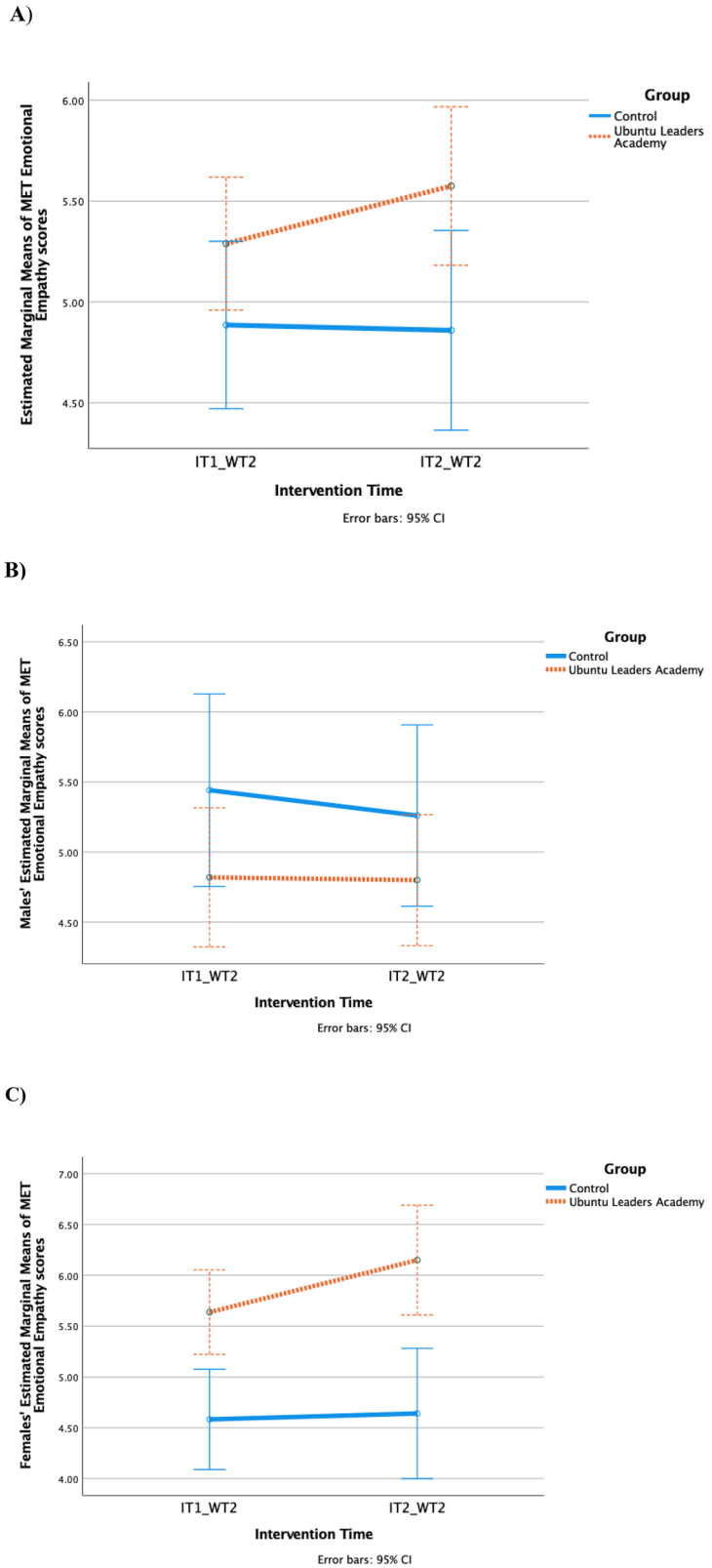

Fig. 3 Plot of emotional empathy scores as a function of group, and intervention T1-WT2 and T2-WT2. A in box sexes; **B** in males; **C** in females.

intervention group but was specific to the first time the task was played (regarding this, see discussion of H2 next). As expected, the impact of the task on oxytocin levels was verified across intervention groups, and before ULA training or the normal school week (i.e., of the control group) took place. The finding that participating in this bonding task stimulates the release of central nervous system oxytocin levels – which are putatively reflected in the saliva (Kosfeld et al. 2005) - is consistent with a plethora of previous data positively relating oxytocin levels and bonding activities, such as conversing, touching, synchronizing

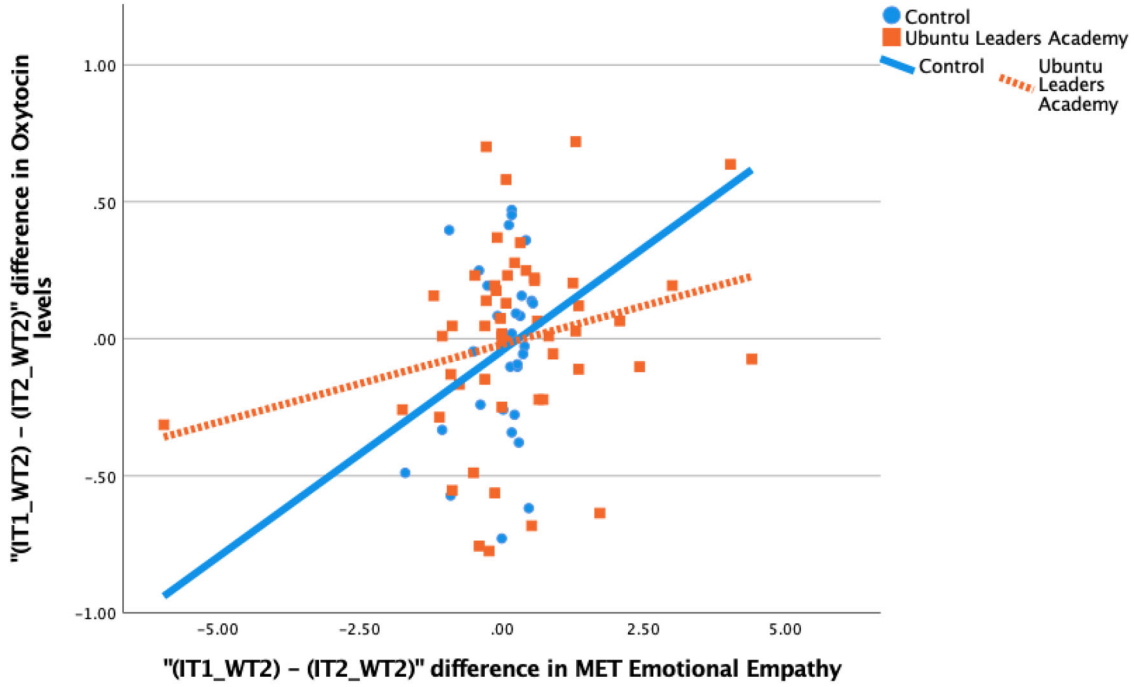

Fig. 4 Plot of the change in emotional empathy versus change in oxytocin levels (at IT1-WT2 vs. IT2-WT2) in both groups.

movement, sharing a meal, etc. (Bellosta-Batalla et al. 2020a; Bellosta-Batalla et al. 2020b; Feldman et al. 2016; Guastella et al. 2008), and consubstantiates: (1) the role of this neuropeptide/hormone in bonding and in the related skill of emotional empathy; and (2) the bonding and empathy-inducing effects of the servant leadership ALU training, given that the Wool Web Task is a core task carried out during this one-week programme.

H2 - Ubuntu training did not augment the above task activity-oxytocin increase. The hypothesis that the above-discussed Wool Web Task-induced increase in oxytocin levels in ULA training participants would be even larger on the second time the task was performed (i.e., on the last day of the week) and specifically in the ULA participants, was not supported by our data. In fact, the impact of the Wool Web task was significantly moderated (explaining 8% of variance) by whether it was the first or the second time subjects played it, showing an effect only on the first time, regardless of group, i.e., ALU training. This was likely found because the bonding-like experience of the task is much stronger the first time it is played and loses impact once it is repeated in the same setting and/or with the same group of people, and in this case, within a short interval of four days. This is consistent with the idea that oxytocin is involved in the habituation to social challenge and novelty, being increased by social support (Grewen et al. 2005), and that its endogenous release may occur only as long as there has not been sufficient habituation to the social stimulus or context. Indeed, as mentioned earlier, oxytocin has been found to decrease with the continuation of social group activity, such as after choir group singing (Schladt et al. 2017) or familiarization-habituation in a social experimental task (Tops et al. 2013).

H3 – Ubuntu training suggestively increased emotional empathy in females. The present data suggestively supports our hypothesis that undergoing the ULA training increases emotional empathy - with it explaining 5% of the variance left unexplained by other factors – and not cognitive empathy. By the last day of the intervention, ULA trainees had increased their emotional empathy (compared to the first day of the week), but controls showed no increase. Given that inspection of the plotted data was suggestive of a time by intervention interaction, it is possible that an interaction did not attain statistical significance due to insufficient power/sample size. This suggestion of an interaction is also supported by leadership training programmes (Feldman et al. 2016; Kosfeld et al. 2005), and socio-emotional training in general (Bellosta-Batalla et al. 2020a; Bellosta-Batalla et al. 2020b), being shown to produce a positive impact in emotional empathy skills (Brondino et al. 2017; Geng et al. 2018; Le et al. 2020) - although these studies have mostly used self-reported questionnaires rather than tasks/performance-based measures. As such, we believe that although our behavioural emotional empathy findings are preliminary, they support that servant leadership training objectively increases emotional empathy. Regarding cognitive empathy, as said, we found no effect of time or intervention. This is consistent with other studies (e.g., (Dadds et al. 2012; Pecukonis, 1990)) where increases in cognitive empathy were not significant, but inconsistent with previous evidence (e.g., (Begeer et al. 2011; Schonert-Reichl et al. 2015a)) where an improvement in cognitive empathy was found after SEL intervention. The effectiveness of SEL programmes can be influenced by the tools used to measure outcomes. For instance, as said above, some studies report significant improvements in cognitive empathy using specific measures, while others, for example, do not (Castillo et al. 2013; Haut et al. 2019). One possible explanation for the absence of effects on cognitive empathy can be related to methodological factors, such as the sensitivity of the measures used to detect changes in cognitive empathy or the duration of the intervention. If the tools used in the study were not sensitive enough to detect changes in cognitive empathy, this could explain the lack of observed improvement. The nature of the intervention could also play a role, which may have primarily targeted emotional rather than cognitive aspects of empathy. Additionally, cognitive empathy might require more explicit training or prolonged exposure to specific perspective-taking strategies to show measurable improvements. Indeed, studies suggest that while affective

empathy can be influenced by interventions, cognitive empathy might require more targeted and sophisticated approaches (Maxwell and DesRoches, 2010; van der Stouwe et al. 2018). Longer and more intensive programmes tend to show more significant results (Castillo et al. 2013). If the SEL training was relatively short or not intensive enough, it might not have been sufficient to produce measurable changes in cognitive empathy. Future studies could explore these aspects further to better understand the conditions under which cognitive empathy can be effectively enhanced.

Regarding again the main effect of intervention group on emotional empathy, we found that it was specific to females, where it explained a large 24% of the variance in this skill. One possible explanation for this gender-specific effect is that women generally tend to score higher on baseline measures of emotional empathy (Stuijfzand et al. 2016), which might create more room for improvement when engaging in targeted interventions. It is also possible that socialization processes and gender norms play a role, as they may encourage greater emotional expressiveness and empathic concern from a younger age in females compared to males. This cultural conditioning could make interventions more aligned with their social roles and expectations (Garaigordobil and Sarrionandia, 2014; Stuijfzand et al. 2016). These suggest that a combination of biological, psychological, and social factors might contribute to the observed gender differences in the effectiveness of SEL interventions. These possibilities warrant further investigation to better understand the mechanisms underlying gender differences in intervention outcomes. Again, given that an intervention by time interaction remained not statistically significant even in females alone, the restriction of the effectiveness of the ALU training in emotional empathy should be considered suggestive, preliminary, evidence to be further scientifically ascertained with a larger and independent randomized-controlled trial of a servant leadership training programme.

H4 – Emotional empathy increase (from first time to second time playing the Wool Web Task) was correlated with an oxytocin increase, regardless of ALU training. Our hypothesis of a potential increase in emotional empathy being reflected in a concomitant increase in salivary oxytocin levels was supported by the present data. Indeed, the two increases – both obtained as the difference between empathy/oxytocin scores/levels at the moment immediately after the two Wool Web Task performances, were positively correlated with a 5% shared variance. This effect was larger (explaining 7% of shared variance, and with a $p = 0.066$) in the ALU group than in the control group (where it explained only 2% of shared variance), which may be suggestive of an empathy-oxytocin association being mostly attributed to the ALU training. This suggestion is only tentative since a moderation by group was not statistically significant (data not shown), and since the ALU group was almost two-times larger than the control group. As such, it should be explored in further larger-sample studies.

Nevertheless, this finding, together with the above-mentioned ones, gives credence to the notion of endogenous oxytocin release being a central physiological mechanism underlying an increase in an empathic behavioural response. It also supports that this response can be triggered by a task which induces feelings of bonding (the Wool Web Task) and – tentatively - that it can be facilitated by training in socio-emotional training for servant leadership such as the ALU programme.

Limitations. This study has some limitations. First, the sample was mainly male, although this difference was balanced between ULA and control groups, and the ULA group was older than the control group although the mean difference was only 0.6 years, thus unlikely to have influenced the reported results. Second, although our sample size ($N = 88$) was similar to a previous study reporting differences in salivary oxytocin levels following a mindfulness and compassion-based intervention ($N = 90$) (Bellosta-Batalla et al. 2020a) and larger than a second study ($N = 68$) (Bellosta-Batalla et al. 2020b), it may still be the case that our sample had insufficient statistical power to detect true effects. Another limitation is the non-blinding of those applying the intervention (as they were all trained ULA tutors), nor of the participants (due to logistic difficulties); however, the researchers performing data analysis were blinded. Lastly, factors that might affect oxytocin levels, such as stress, menstrual cycle or diurnal variability have not been considered/collected. Given its limitations and unprecedented research questions, future research should aim to build on these results, for example, by exploring long-term effects of SEL on biological markers and employing more demographically diverse samples.

Conclusion and further research. We conducted a study using the Ubuntu Leadership Academy (ULA), a worldwide and rapidly growing servant leadership SEL training programme, and its specific Wool Web Task activity as a case study. Our investigation focused on the potential role of oxytocin, a key neuropeptide, as a modulator of empathic skills. The recent Multifaceted Empathy Test served as a comprehensive measurement tool. Our findings suggest a preliminary positive impact of the ULA training on emotional empathy, and of its Wool Web Task, on endogenous oxytocin release. Namely, we found that salivary oxytocin was increased after the Wool Web Task, but ULA did not augment this oxytocin increase. We also found that Ubuntu training tentatively increased emotional empathy, but only in females. Lastly, an emotional empathy increase (from the first time to the second time playing the Wool Web Task) was correlated with an oxytocin increase, albeit regardless of ALU training. Such findings are broadly consistent with current oxytocin knowledge and expectations of empathy increases due to socio-emotional training. However, these findings are preliminary and tentative. Further research is warranted to replicate and consolidate them, in particular the suggestive statistically non-significant trends, in an independent and larger sample. Additionally, we suggest future lines of neuroscientific research, inspired by our work and which might support it, such as investigating: (1) whether intranasal oxytocin might induce adolescents to perform better in SEL; or (2) an effect on SEL on endogenous levels of other hormones with known impact in social behaviour such as testosterone and cortisol; and (3) an effect of genetic background pertaining to these hormonal systems on SEL performance, and/or if, reversely epigenetic methylation changes might occur as a consequence of SEL exposure. Resulting findings could prove useful in the design of a better physiologically informed mechanistic model of SEL as well as of clinically useful diagnostic methods for those with higher SEL difficulties, and therapeutic/adjuvant solutions for SEL.

In sum, this study contributes to the existing literature on SEL in several ways. First, unlike many previous studies that rely primarily on self-report measures, we employed an RCT design with objective and quantitative assessments, including salivary oxytocin as a neurobiological marker. This allows for a more rigorous evaluation of the effects of SEL on both behavioural and physiological outcomes. Second, while SEL interventions often span several weeks or months, our study examined the effects of a short, 1-week intervention, providing insights into the potential for rapid changes in empathy-related processes. Third, we specifically investigated the role of a group-bonding task in modulating oxytocin levels and its association with changes in

emotional empathy, an area that remains underexplored in SEL research. These findings help to bridge gaps between SEL, social neuroscience, and biological mechanisms underlying empathy, offering a novel perspective on how social bonding experiences may enhance socio-emotional competencies.

Data availability

Data and study materials are available upon request to corresponding author.

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Author contributions

DP conceptualized, designed, obtained funding for, and supervised the study, and analysed the data, and drafted the manuscript. SF co-drafted the manuscrupt. AR conducted data collection and revised the paper.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethics approval for the all parts of this study was given the Portuguese ISCTE-IUL university ethics commission (Ref 67/2021), before research activities started. Research was performed in accordance with the Declaration of Helsinki.

Informed consent

The parents of all participants signed an informed consent form for participation, data use and consent to publish, before participation. Participants have been fully informed that their anonymity is assured, why the research is being conducted, how their data will be utilised, and if there were any risks to them of participating.

Additional information

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