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The Role of Physical Activity and Touch in Children's Social Bonding

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Physical activity (PA) and touch, long known to facilitate interpersonal affiliation in adults and non-human primates, are common elements of children's free play. However, no research has examined how children's play involving PA and touch is linked with social bonding (i.e., positive emotional states and behaviors that help create, maintain, and characterize affiliation and attachment among individuals). This paper reports on two novel studies designed to explore these links in children's play. In two studies, we investigated associations between PA, touch, and prosociality in 5-to-8-year-old children. In a naturalistic observation study ($N = 50$), we assessed the amount of PA, smiling/laughing, touch, and prosociality in children's play behavior during school breaks. PA levels were also measured indirectly via heart rate monitors (HRM). The findings revealed that observed-PA was associated with frequency of smiling/laughing between pairs. PA (observed and HRM) was also associated with frequency of touch. In a second study ($N = 84$), we experimentally tested the effect of touch on helping behavior in the context of physically-active play. In pairs, children ran to collect felt shapes, which they placed either onto each other (touch condition) or onto a board (no-touch condition). Subsequent helping behavior was assessed in a separate task. There was a non-significant trend towards more helping in the touch condition. We discuss the findings in terms of the significance of PA and touch for social bonding in childhood and offer suggestions for future research in this underexplored area.

Keywords: Touch, social bonding, physical activity, play

Establishing and maintaining strong social bonds is crucial for humans from early infancy and childhood. Here, social bonding is taken to refer to positive emotional states and behaviors that create, maintain, and characterize affiliation and attachment among individuals. In children, it has typically been assessed by measures of emotional closeness, connectedness, cooperation, and prosocial behaviors such as helping (Eisenberg, Fabes, & Spinrad, 2006; Kirschner & Tomasello, 2010; Tunçgenç & Cohen, 2015) or sharing (Fehr, Bernhard, & Rockenbach, 2008). Although there is a relatively rich tradition of research on the earliest bonds between infants and primary caregivers (e.g., Bellieni et al., 2007; Feldman, Eidelman, Sirota, & Weller, 2002), causal mechanisms involved in social bonding in childhood are only beginning to be scientifically established. Two common features of human interaction and of children's play – physical activity (PA) and touch – stand out as potentially important contributors to social bonding.

Mounting neurobiological, comparative, and developmental research, reviewed below, provides a foundation for a link between social reward and PA (see Physical Activity and Social Bonding) and touch (see Touch and Social Bonding). Although studies have established links between PA and social bonding among adults (Di Bartolomeo & Papa, 2017; Cohen, Ejsmond-Frey, Knight, & Dunbar, 2010) and between touch and social bonding among non-human primates (Dunbar, 2010; Seyfarth & Cheney, 2012; Silk, 2007; Silk et al., 2010; Wittig et al., 2008) and human infants (Feldman et al., 2002; Field, 2010), no study to date has

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systematically investigated the links among social bonding, PA, and touch in children. The two studies reported here explore whether PA and touch play a role in facilitating social bonding in children during peer-play.

Physical Activity and Social Bonding

The benefits of PA span a wide range of physical health outcomes (Janssen & LaBlanc, 2010; Reiner, Niermann, Jekauc, & Woll, 2013; Warburton, Nicol, & Bredin, 2006). Research with school-aged children has shown that PA, and moderate-to-vigorous physical activity (MVPA) in particular, is associated with positive physical and cognitive health (Álvarez-Bueno et al., 2017; Boddy et al., 2014; de Greeff, Bosker, Oosterlaan, Visscher, & Hartman, 2017). In contrast, the benefits to social-emotional health are less well understood, and social outcomes from MVPA in childhood have received less attention still (but see Colwell & Lindsey, 2005; De la Haye, Robins, Mohr, & Wilson, 2011; Lindsey, 2014).

The existing literature on children's PA suggests some links between engagement in MVPA and social behaviors relevant to bonding. For instance, a comprehensive observational study across 40 schools (involving 747 children) in the UK investigated correlations between the everyday MVPA levels of friends. Children wore accelerometers, yielding objective physical activity readings, for five consecutive days. Spatial autocorrelation was used to analyze the relationship between children's MVPA and self-declared degrees of separation (children nominated and ranked up to four peers as friends). Mean daily MVPA levels were positively correlated among closer (immediate and second degree) friends. As children's degree of separation increased (from immediate friends to fifth degree friends), similarity in mean MVPA decreased (Macdonald-Wallis, Jago, Page, Brockman, & Thompson, 2011). Other research on children's PA and sociality has shown that higher amounts of MVPA are associated with larger group sizes (Sanders et al., 2014; Roberts, Fairclough, Ridgers, & Porteous, 2013; Ridgers, Stratton, & McKenzie, 2010; Woods, Graber, Daum, & Gentry, 2015). Even the presence of a single friend can increase children's PA almost threefold (measured in accelerometer counts) compared to being alone (Sanders et al., 2014). Furthermore, some studies have found that children enjoy PA more when they are with their friends (Rittenhouse, Salvy, & Barkley, 2011; Sanders et al., 2014). A recent study found that for 8- to 12-year-old children, time spent in MVPA was associated not only with the children's reported liking of PA, but also with how motivated they were to engage in their favorite PA relative to a sedentary activity (i.e., watching their favorite cartoon, Roemmich et al., 2008). These behavioral findings on children's play that suggest a bidirectional relationship, such that greater PA engagement and enjoyment are observed when children are in the company of close friends, and that increased enjoyment levels are associated with higher PA engagement. This supports the idea that facilitated reward and enjoyment mechanisms mediate the relationship between PA and social bonding.

Investigation of neurobiological mechanisms provide further support for this proposal. Endogenous opioids (e.g., endorphins), which play a crucial role in pain management and reward processing (Leknes & Tracey, 2008), are also thought to be implicated in social bonding (Inagaki, Ray, Irwin, Way, & Eisenberger, 2016; Machin & Dunbar, 2011). Importantly, research with adults suggests that exertive PA elevates endorphin levels (Boecker et al., 2008) and resistance to pain (Cohen et al., 2010). A recent study with high school children assessed participants' pain thresholds before and after performing either high or low exertion dance movements with others. The study revealed that participants in the exertive dance conditions had significantly higher pain thresholds and self-reported social closeness compared to those in the low exertion conditions (Tarr, Launay, Cohen, & Dunbar, 2015). These findings support the idea that PA facilitates social bonding in part via the release of endogenous opioids.

There is also some evidence for an exercise-induced opioid response in younger children. For example, one study investigated the influence of puberty on the β-endorphin response to exercise among prepubertal and pubertal children. Children completed a single 15-minute cycling session on an ergometer with increasing workload such that HR reached 90% of the maximal value during the last 5 minutes. Blood samples were taken just before the session commenced, just after the session, and after a recovery period of 10 minutes. There was a significant increase in plasma β-endorphin levels immediately following the 15 minutes of cycling and levels remained significantly elevated even after the 10 minute recovery period (Bouix et al., 1994). This study suggests that there may be a similar opioid response to exercise in children as in adults. However, no studies to date have extended this work to examine possible links with social bonding.

Research across species provides further insights into the neurohormonal response to physical play in social animals, such as rats. For instance, Trezza, Damsteegt, Achterberg, & Vanderschuren (2011) found that exogenously stimulating opioid receptors in the nucleus accumbens (a brain region associated with positive social interactions in humans; Güroğlu et al., 2008) increased pinning and pouncing behavior in rats, while blocking the opioid receptors in this region disrupted these enhancement effects. In addition to opioids, studies with rats suggest a role for the brain's dopamine system in regulating play behavior (Burgdorf, Wood, Kroes, Moskal, & Panksepp, 2007). The dopamine system is closely associated with reinforcing value ("wanting") of, for example, addictive drugs and tasty food in humans, but is also known to play a significant role in maternal behavior in rats (Lee, Clancy, & Flemming, 2000; Mattson, Williams, Rosenblatt, & Morrell, 2001) and pair-bonding in prairie voles (Gingrich, Liu, Cascio, Wang, & Insel, 2000; Wang et al., 1999). Although animal models have limited applicability for questions about human cognition and behavior, these findings suggest possible underlying mechanisms by which MVPA and social behavior are linked.

Prior behavioral, neurobiological, and comparative research suggests strong associations between PA engagement, enjoyment, and social bonding, and are possibly mediated by activation of endogenous opioids and the dopamine system. To investigate these links behaviorally in children, the current studies examined how PA levels are associated with both enjoyment (e.g., smiling and laughing) and social bonding (e.g., helping and interpersonal liking).

Touch and Social Bonding

Touch is a fundamental feature of primate sociality due to its role as a facilitator and signal of interpersonal intimacy. Based on observational accounts of non-human primates, it is thought that touch fulfills an evolved social bonding function in the form of social grooming (Dunbar, 2010; Seyfarth & Cheney, 2011). For instance, among female wild gelada baboons, there is a significant correlation between time spent with a grooming partner and aid shown towards the partner in conflict situations (Dunbar, 1980). Further, grooming relationships are stable and persistent, sometimes lasting years, allowing the formation of strong alliances (Silk, 2007; Silk et al., 2010; Wittig et al., 2008).

In humans, touch is the first sense organs to develop in infancy and, in infancy, develops before all others (Field, 2010; Montagu, 1971). One of the first experiences of a newborn baby is social touch – first being assisted from the mother's body by a doctor or midwife, then handed carefully to the parents for cuddling and nurturing. A recent longitudinal study suggests that skin-to-skin care (sometimes referred to as "Kangaroo Care") given to preterm infants is associated with improved emotional, cognitive, and physiological development (i.e., attenuated stress response, improved respiratory sinus arrhythmia, organized sleep, and better cognitive control) throughout the first 10 years of life (Feldman, Rosenthal, & Eidelman, 2014). When skin-to-skin care is practiced, the mother also enjoys a range of benefits such as improved positive affect, improved ability to read her infant's cues, and lower likelihood of postpartum depression (Feldman et al., 2002). These effects help facilitate secure attachment between the infant and mother and provide the infant with a foundation for future social relationships (Duhn, 2010).

Experimental evidence also suggests a link between touch and social behavior in adults. For example, even a brief touch (one to two seconds) to the arm or shoulder can influence behavior, such as increased compliance with a request (Guéguen, 2002; Joule & Guéguen, 2007; Kleinke, 1977) or increased amounts of spontaneous helping towards the toucher (Guéguen & Fischer-Lokou, 2003; Paulsell & Goldman, 1984). Brief touch also positively influences social perception, such as how people rate their experience in a library (Fischer, Rytting, & Heslin, 1976) or evaluate a salesperson's personal attributes at a car showroom (e.g., friendliness, sincerity, kindness, honesty, and agreeableness, Erceau & Guéguen, 2007). Hertenstein and colleagues (2006) further showed that distinct emotions can be conveyed between strangers through touch, even without seeing or hearing one another. Participants were positioned on either side of a curtain; one participant was designated as the encoder and the other as the decoder. The encoder was given a number of emotions to convey to the decoder by only touching their arm. The decoder then had to determine the touch message conveyed by choosing from a list of possible emotions. Decoders were able to distinguish distinct emotions –fear, anger, disgust, love, gratitude, and sympathy– seven times higher than chance levels. Touch potentially offers a medium for communicating emotions, which, in turn, can facilitate trust, cooperation, and social bonding (Boone & Buck, 2003; Loomis, 1959).

Several neurohormonal mechanisms have been proposed to link touch to social bonding. Similar to their proposed role in mediating the PA-social bonding relationship, endorphins have been proposed to mediate the links between touch and social bonding (e.g., grooming behavior) in non-human primates (for a review, see Dunbar, 2010). In addition, oxytocin is thought to play a crucial role in mother-infant bonding in humans (Feldman, Weller, Zagoory-Sharon, & Levine, 2007; Feldman, 2012) and pair-bonding in mammals more generally (Bales et al., 2007; Smith, Ågmo, Birnie, & French, 2010; Williams, Insel, Harbaugh, & Carter, 1994). Some studies show that administration of exogenous oxytocin can promote nurturing (Pedersen & Prange, 1979; for review, see Bosch & Neumann, 2012) and affiliative behavior in rats (Calcagnoli, Kreutzmann, de Boer, Althaus, & Koolhaas, 2015) and social bonding (indicated by affiliation, approach, and time spent in physical proximity) in dogs (Romero, Nagasawa, Mogi, Hasegawa, & Kikusui, 2014, 2015). Oxytocin may also influence affective responses to social touch in humans (Light, Grewen, & Amico, 2005). Several studies have documented positive physiological and biological responses to touch, including decreased cortisol (stress hormone) levels (Ditzen, Hoppman, & Klumb, 2008; Feldman, Singer, & Zagoory, 2010), increased oxytocin (Light et al., 2005), and lower blood pressure (Holt-Lunstad, Birmingham, & Light, 2008; Light et al., 2005). Thus, social touch can lower stress, trigger oxytocin release, and thereby create a psychological environment conducive to positive social engagement.

Although the social effects of touch have been widely reported in infants and adults, evidence in young children is limited to a few studies in which touch is largely adult-directed. Qualitative ethnographic studies have reported that touch is often combined with verbal directives from adults to monitor and guide children's behaviors (Cekaite, 2010, 2016; Goodwin & Cekaite, 2013; Meyer, Streeck, & Jordan, 2017) and to teach them social norms (Burdelski, 2010). Studies from educational contexts support a link between teacher-directed touch (e.g., touch accompanied by praise) and improved on-task behavior by the students (Wheldhall, Bevan, & Shotall, 1986), as well as improvements in emotional development and mood, and reduced stress (Owen & Gillentine, 2011).

Together, these studies indicate that touch may be linked with social bonding via activation of pain and stress management mechanisms and by positively affecting children's social behaviors in a variety of contexts. However, controlled experimental studies are needed in order to systematically isolate and examine the behavioral effects of touch. Furthermore, prior studies have only considered the effects of touch from adults to children while children's daily lives are rich with peer interactions. Thus, the current studies examined how touch is linked with positive social behaviors (e.g., helping, cooperative play) in peer interaction contexts.

Aims and Hypotheses

As summarized above, behavioral, psychological, and neurobiological findings on children's and animals' play and attachment behavior, as well as adults' exercise behavior, suggest that PA and touch may be important factors that facilitate social bonding in children. To explore these relationships more systematically, we first conducted an observational study (Study 1), in which children's behavior was observed as they engaged in spontaneous play with their peers. In addition to observational coding of PA levels, heart rate monitors (HRM) were fitted as a supplementary measure of children's PA levels (see also: Gallotta et al., 2012; Wang, Pereira & Mota, 2005). An observer also recorded several behavioral measures, namely smiling/laughing, touch, and prosocial behavior. Smiling and laughing were coded as indicators of enjoyment (Tunçgenç & Cohen, 2016), while touch (Feldman et al., 2007; Feldman et al., 2010; Feldman, 2012) and prosocial behavior (Davis, Taylor, & Cohen, 2015; Dunbar & Schultz, 2010) were assessed due to their theorized links with social bonding. We hypothesized that MVPA would be positively correlated with frequency of smiling/laughing, touch, and prosocial behavior.

In Study 2, we conducted an experiment to test the hypothesis that touch, as compared to no touch, would facilitate prosocial behavior in the context of MVPA. In this study, the children played a game that required them to engage in MVPA while placing shapes made of felt either onto each other (touch condition) or onto a board adjacent to their play partner (no-touch condition). Subsequent helping and self-reported liking of the play partners were analyzed. Following precedent in the literature (Kirschner & Tomasello, 2010; Tunçgenç & Cohen, 2016), helping behavior and self-reported liking were used as measures of social bonding.

Study 1

We conducted an observational study to explore whether PA levels (and MVPA in particular) in children's free-play is associated with enjoyment, touch, and pro-social behaviors.

Method

Participants. Fifty-three children (22 male, M_{age} = 6.9 years, range: 5.2 - 8.6 years) from three local elementary schools in Oxford, UK were recruited. Prior to the study, informed consent was obtained from parents. Ethics clearance was received from the University of Oxford central university research ethics committee. Data from three children were removed from the analysis due to two children becoming unobservable for over half of the observation period and one child spending all of the time with a teacher, leaving a total of 50 participants (22 male, M = 6.8 years, range: 5.2 - 8.6 years).

Materials. A playground observation study was conducted during children's school breaks. Observation sessions took place at outdoor playgrounds in three schools from March 2016 to July 2016. Using a focused, momentary time sampling method (McKenzie & Van Der Mars, 2015), children's behaviors were recorded every 20 s (10 s to observe, 10 s to record) across 10 min for a total of 30 observations per child. The observer (first author, M.J.) recorded the observations using pen and paper while an in-ear audio prompt informed her of the time intervals indicating when to start observing and recording. Heart rate (HR) data were obtained as an additional indirect measure of PA using Polar HRMs attached to each participant.

Procedure. Only one child was observed at a time and each observation session lasted 10 min. Prior to being observed, the HRM, composed of a chest strap and a wrist watch, was fitted to the child. The chest strap was applied directly to the skin and tightly secured around the child's chest and the watch was applied to the upper arm with a piece of paper taped over the screen. The observation session started following a brief lunch (in two of the schools) or snack break (in one school).

Throughout the observation session, the experimenter maintained a distance of not more than 15 m from the focal child. This allowed enough distance for the focal child to be within clear sight of the experimenter without being ostensibly close. Children were given no indication of when the observations began or ended. When the play break finished, the experimenter approached the focal child and removed the HRM before the child returned to the classroom. The whole procedure lasted for approximately 15 min per child.

Coding and data preparation. The coding scheme was adapted from the System for Observing Children's Activity and Relationships during Play (Ridgers, Stratton, & McKenzie, 2010). Following completion of data collection, the initial coding scheme was revised post-hoc by combining and/or omitting several subcategories due to too high or too low frequencies of occurrence. The initial coding scheme comprised four categories of behavior with the following subcategories: Social context (alone or social), PA (sedentary: e.g., sitting or standing still; light: e.g., slow walking, gentle swinging; or moderate-to-vigorous [MV]: e.g., running, fast climbing), Facial expression (smiling, laughing, or neither), and social behavior (positive engagement with touch, positive engagement (no touch), prosocial behavior with prosocial touch, prosocial behavior with neutral touch, prosocial behavior without touch, antisocial behavior with antisocial touch, antisocial behavior with neutral touch, antisocial behavior with no touch, touch with no positive engagement, prosocial behavior, or antisocial behavior). Detailed descriptions of these categories can be found in the *Supplementary Materials*.

The final coding scheme used for the analysis is shown in Table 1. The following amendments were made on the initial coding scheme to construct the final coding scheme: the categories of social context (due to too high occurrence: 94.14% of all observed cases were social) and antisocial behavior (due to too low occurrence: 0.29% of all observed cases) were omitted from further analysis. The subcategory of laughing (due to too low occurrence: 1.9% of all observed cases) was combined with the subcategory of smiling. Due to too low frequencies of occurrence, the three prosocial behavior subcategories were combined into one general prosocial category called "all prosocial behavior," which represented 3.03% of all observed cases. In order to analyze associations of PA with touch behavior, all categories involving touch were combined into one category called "touch". Due to zero observations of antisocial touch, this combined "touch" category comprised of the previous categories of positive engagement with touch, prosocial behavior with prosocial touch, and prosocial behavior with neutral touch. Thus, social behavior subcategories included "facial expression", "touch", "positive engagement (no touch)", and "all prosocial behavior", each of which were analyzed separately. For each of these subcategories, children received a score of 1 for every instance of smiling/laughing, touch, positive engagement (no touch), and prosocial behavior at each of the 30 observations for that child.

PA levels were coded by giving a score (0 = sedentary, 1 = light PA, 2 = MVPA) to each of the 30 observations of a child. For analysis of observed PA levels, average PA per child was calculated. To assess associations with MVPA, in addition to the observational coding above, HR measurement was also used as an indicator of PA levels. HR data (beats per minute [BPM]) were collected from 46 of 50 participants using the HRMs. Four participants' HR data were dropped from analysis (one due to losing the monitor while playing, one due to clothing interference with readings, and two due to monitor malfunction). The average participant HR was 132.23 BPM (SD = 20.27; males: 131.8 BPM [SD = 19.9]; females: 132.52 BPM [SD = 20.76]). Following the literature on HR that corresponds to MVPA, we used a threshold of 140 BPM (Fjørtoft, Kristoffersen, & Sageie, 2009; Simons-Morton, Parcel, O'Hara, Blair, & Pate, 1988; Wang et al., 2005) and divided the sample into two groups: those whose average HR was at or above 140 BPM (moderate-to-vigorous heart rate, MVHR) and those whose average HR was below 140 BPM (non-MVHR).

Independent-samples t-tests were used to assess statistical differences between gender and age groups for each subcategory. Children were split into "younger" and "older" age groups based on the median age of 6.9 years. Due to the unpredictability of children's movements on the playground (e.g., the observer occasionally losing sight of the children), the number of observations differed from child to child (range: 16-30 observations per child). Hence, we analyzed our non-normally distributed data as a proportion of observations and used beta regression analyses, which assume values in standard unit intervals (e.g., proportions or rates). The beta distribution supports a range from 0 to 1 and can accommodate skewness and heteroscedasticity in the data (Zeileis et al., 2016). Frequencies of smiling/laughing, touch, and prosocial behavior were each converted into proportions and analyzed with the *betareg* package within Rstudio, Version 1.0.143 (2016).

Table 1
Final Coding Categories for Analysis

Main Category	Category Codes for Analysis
Physical Activity (PA)	Sedentary Light MVPA
Social Behavior	Facial expression (Smiling and Laughing or Neither) Touch (Positive engagement with touch, Prosocial behavior with prosocial or neutral touch) Positive engagement (no touch) All Prosocial Behavior (with and without touch)

Results

Descriptive analyses detailing the average percentage of time children spent in each of the behavior categories overall and split by gender are given in Figure 1. Analyses of age differences revealed that older children were more likely than younger children to perform prosocial behaviors, $t(35.49) = -2.14$, $p = 0.039$ while no significant age differences were found for observed PA levels, $t(47.22) = 0.380$, $p = 0.704$, HR, $t(42.59) = 0.68$, $p = 0.498$, smiling/laughing, $t(41.75) = 1.06$, $p = 0.293$, touch, $t(47.98) = -1.17$, $p = 0.247$, or positive engagement (no touch), $t(47.96) = 1.13$, $p = 0.266$.

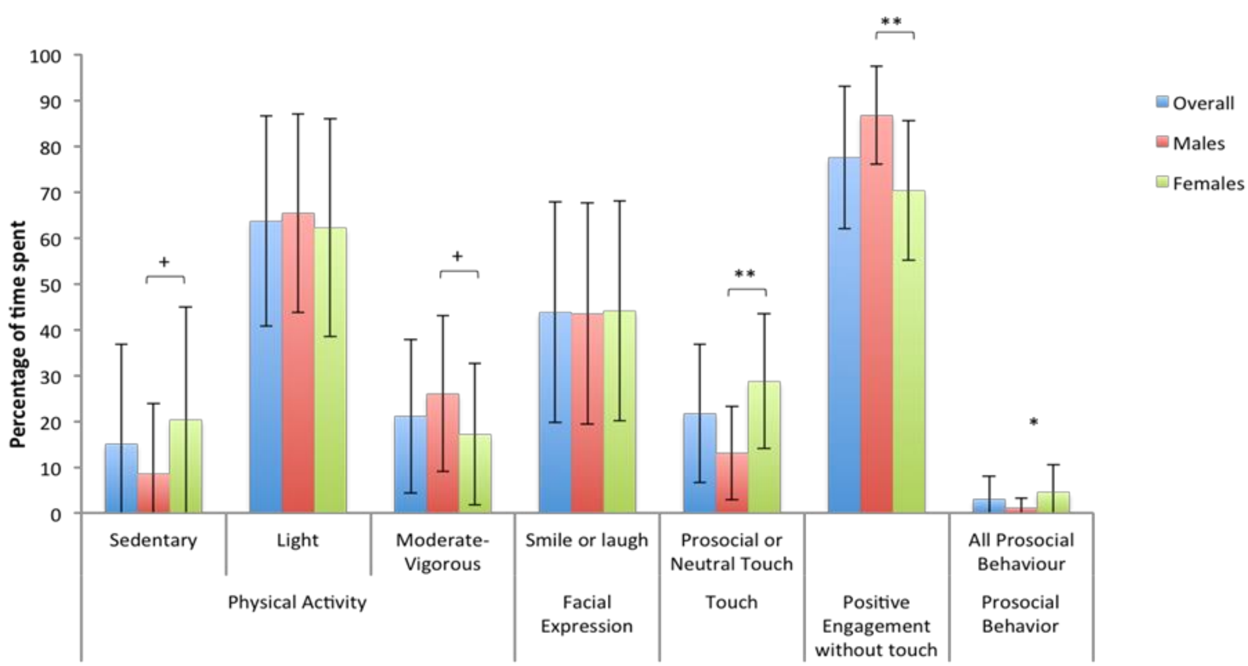
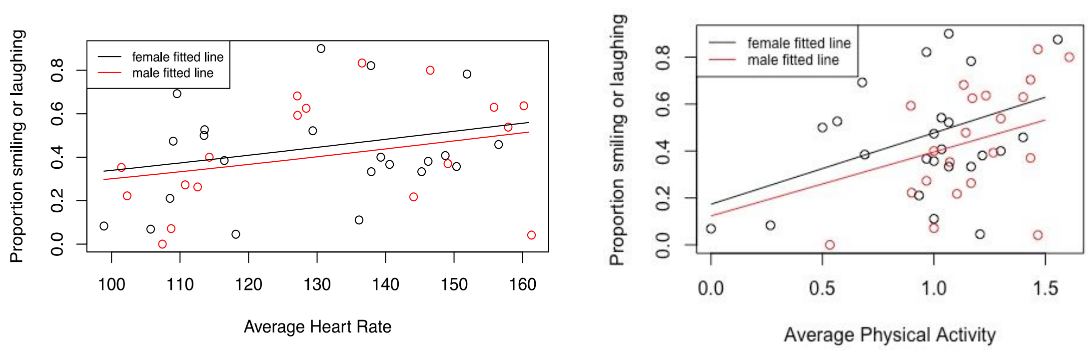


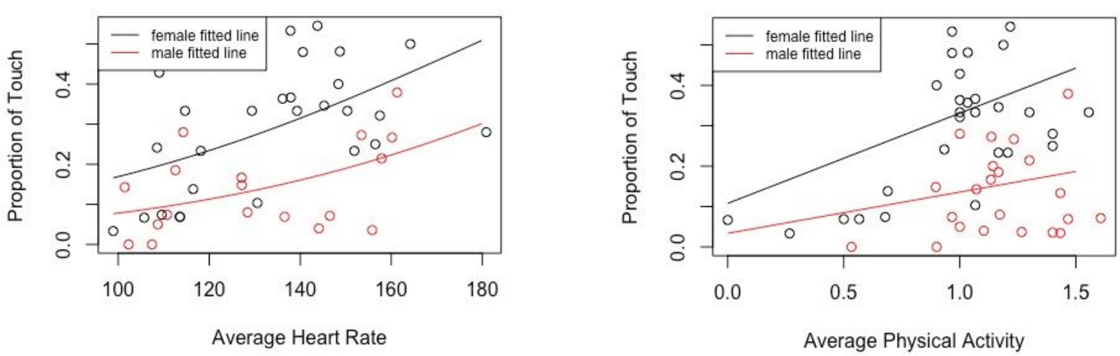
Figure 1. **Average percentage of observations for each category.** Vertical bars indicate standard deviation and connector bars indicate statistical significance. $^{+}p < 0.08$. $^{*}p < 0.05$. $^{**}p < 0.01$.

In order to assess whether PA levels predicted social behavior (smiling/laughing, touch, positive engagement (no touch), and prosocial behavior), two regression analyses were run for each subcategory with observed PA and average HR as predictor variables, controlling for gender (Figure 2). Smiling/laughing was positively predicted by observed PA levels, $\beta = 1.39$, *SE*(0.46), pseudo-$R^2 =$ .22, $p = 0.002$, and marginally positively predicted by average HR, $\beta = 0.01$, *SE*(0.01), pseudo-$R^2 = .09$, $p = .059$. Touch was positively predicted by observed PA levels, $\beta = 1.26$, *SE*(0.33), pseudo-$R^2 = .47$, $p < .001$, and average HR, $\beta = 0.02$, *SE*(0.01), pseudo-$R^2 = .45$, $p < .001$. Furthermore, a t-test revealed that children whose average HRs were moderate-to-vigorous (MV) touched more often ($M = 0.30$) than children whose average HRs were not MV ($M = 0.18$), $t(35.20) = -2.67$, $p = 0.011$. Positive engagement (no touch) was negatively predicted by observed PA levels, $\beta = -1.24$, *SE*(0.33), pseudo-$R^2 =$ .46, $p < .001$, and by average HR, $\beta = -0.02$, *SE*(0.005), pseudo-$R^2 = .45$, $p < .001$. Prosocial behavior was marginally positively predicted by observed PA levels, $\beta = 0.74$, *SE* (0.39), pseudo-$R^2 = .20$, $p = 0.055$, but not by average HR, $\beta = 0.01$, *SE*(0.01), pseudo-$R^2 = .15$, $p = 0.299$). Out of 41 prosocial occurrences, all but one involved touch.

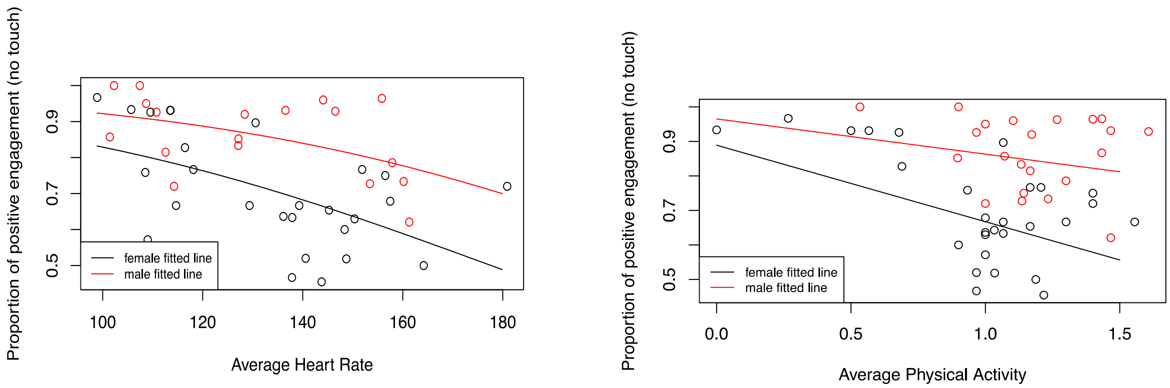
(a) Smiling/laughing



(b) Touch



(c) Positive engagement (no touch)



(d) Prosocial Behavior

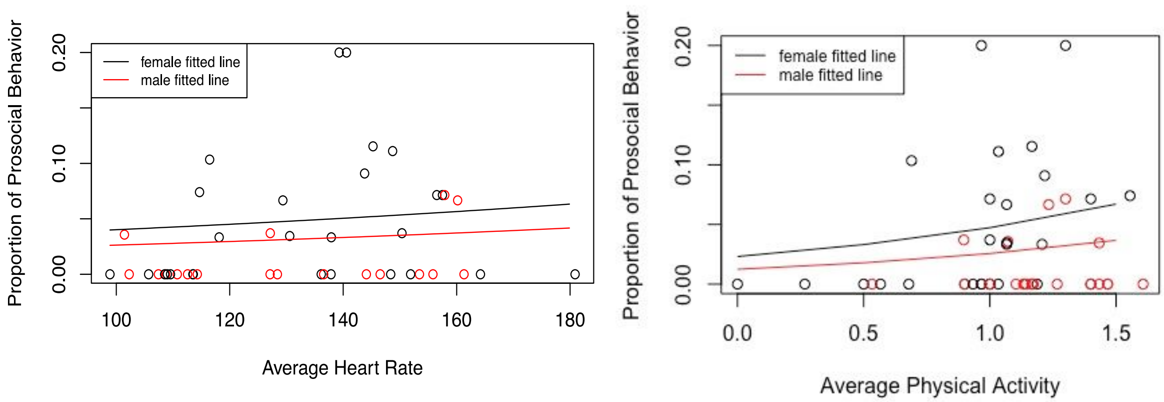


Figure 2. **Regression for the relationship of (a) smiling/laughing (b) touch, (c) positive engagement (no touch), and (d) prosocial behavior with average HR (left panels) and observed PA (right panels), controlling for gender.**

Discussion

This observational study explored the relationship between PA levels and social bonding behaviors (as measured by the frequencies of smiling/laughing, touch, and prosocial behavior) during children's free-play. As hypothesized, analyses revealed that higher levels of observed PA and higher average HR predicted greater amounts of smiling/laughing and touching. Although prosocial behavior was rarely observed, it was found to be more prevalent among girls than boys and more likely to occur with touch than without. The marginal influence of PA on prosocial behavior supports our hypothesis, but warrants further investigation with a larger sample size. Our findings also reinforce previous work by showing that children's PA levels are higher among boys than girls. Confirming previous anecdotal reports (Stier & Hall, 1984), this study revealed that girls touch more often than boys during free-play.

This study was limited by the correlational nature of its design and the small sample size. Still, the findings that touch positively predicted observed PA and that more touch occurred during MVHR as compared to during non-MVHR play suggest that high-energy physical play may be an important context for social touch. This, in turn, may be associated with prosocial behavior. We designed an experimental study (Study 2) to test the hypothesis that touch taking place in a physically-active play setting facilitates prosociality among children.

Study 2

The aim of this study was to experimentally assess whether PA levels and touch influence prosociality in children's play. The design and hypotheses of this study were motivated by results of Study 1 showing that (a) much of children's physically active play involves touch, (b) touch occurs more frequently during MVPA than non-MVPA play, and (c) prosocial behaviors are almost always accompanied by touch. We hypothesized that children who experienced touch from their play partner during a game would subsequently help their partner more and would report greater liking of their partner as compared to children who did not experience touch during the game.

Method

Participants. A power analysis conducted prior to the experiment based on two previously published studies using the same dependent variable measure with similar age groups (see Kirschner & Tomasello, 2010; Tunçgenç & Cohen, 2016) yielded a sample of 88 children (i.e., 44 pairs). We recruited 128 children from public and private schools and after school programs in the metropolitan area of Houston, Texas, yielding 64 pairs of participants. Children were first organized by gender and age, followed by random pair assignment. If teachers reported a pair to be "best friends" or to "not play well together", they were re-randomized to ensure consistently neutral pair assignment. Our final sample included 84 typically-developing children (46 girls, M = 6.63 years, SD = 0.85; range: 62.2 – 102.5 months) from mixed socio-economic backgrounds. Twenty pairs (40 children) were removed from analysis due to equipment failure (e.g., toy did not break; 10 pairs), mismatch of age within pairs (4 pairs), experimenter error (3 pairs), interference of a passer-by (1 pair) and children not following the instructions (2 pairs). A further two sessions were later dropped from analysis because the video recordings of these sessions were inaudible (2 pairs), which prevented accurate assessment of whether the help observed was spontaneous or solicited. The study was approved by the University of Oxford central university research ethics committee and written permission was obtained from the schools and organizations as well as from the children's parents/guardians.

Materials. In a between-subjects design, children were randomly assigned to one of two conditions: touch or no-touch. Touch occurred in the context of a game activity that was designed to be similar to those commonly observed in children's natural play (i.e., touching on the arms and back, sweeping, and whole hand pressure) and that was otherwise identical between conditions. The dependent variable, prosociality, was measured by evaluating the level of help demonstrated in a specially-designed game adapted from Kirschner and Tomasello (2010), in addition to a single, Likert-scale question assessing partner liking. For purposes of reliability-checking, all sessions were video recorded, and two researchers blind to the hypotheses and conditions coded the sessions for helping behavior.

Procedure. The experiment procedure was comprised of a warm-up activity (Animal Game) followed by two main tasks (Shape Game and Fish Feeding Game) and concluded with the partner liking assessment. The study took place in a room or open space in the children's school, away from other children and regular school activities. Children were brought into the study area in same-sex pairs, one pair at a time.

Animal Game (warm-up/training activity). In the Animal Game, children were asked to pretend to be birds and frogs, and subsequently rated how much they enjoyed behaving as each animal on a 6-point Likert scale. The same Likert scale was used at the end of the experiment to indicate partner liking.

After this initial warm-up phase, children were given further instruction to "find a bird shape" or "find a frog shape" in a pile of cut-out felt shapes on the other side of the room and attach it to a board located 3 m away. The experimenter demonstrated the task first, showing how the shapes must be securely fixed to the board, inside the traced shape lines. The children repeated the task twice, once for each shape. This part of the warm-up activity served as training for the Shape Game.

Shape Game. This game was designed for this study to assess the effect of touch versus no-touch in a physically active play context. In the Shape Game, one child was randomly assigned (prior to the session) to be the first to wear a yellow jacket, which had 10 bird and 10 frog outlined shapes covering the arms and back (see Figure 3). This jacket was called the "frozen" jacket, because once placed onto the child, the child had to stand still and refrain from all movement. The child in the frozen jacket was instructed to stand next to a 20" x 29" sized board propped upright on the floor, covered in the same yellow material with the same shapes as the jacket (see Figure 3). In the meantime, the other child was instructed to run to the pile of bird and frog shapes at a distance of 3 m away and collect one shape at a time to attach to the corresponding outline shapes on the frozen jacket (touch condition) or to the corresponding shapes on the board (no-touch condition). The child fetching the shapes was told to continue doing so until the experimenter (*E*) said to stop, at which point the children would switch roles. *E* always told the children to stop as soon as they attached the 10th shape to the target to ensure that both children experienced a similar amount of touch. Once both children had their turns in each role, *E* counted all the shapes to minimize any competition the children may have felt during the game.

(a) (b) (c)

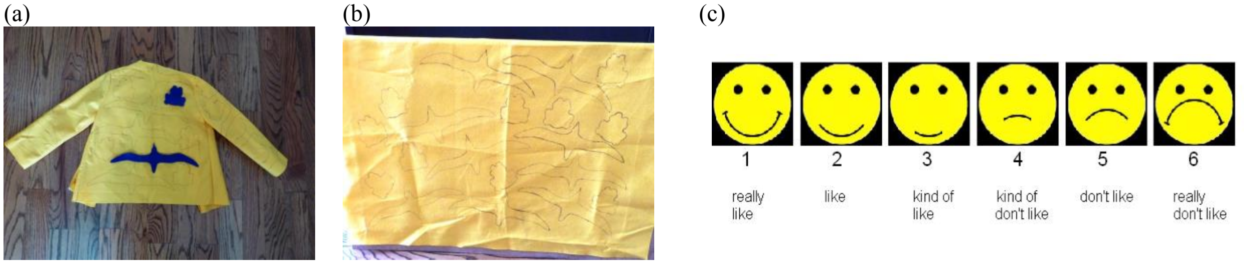


Figure 3. **Experiment materials: (a) jacket, (b) board for The Shape Game, and (c) partner liking scale.**

The Fish Feeding Game. The Fish Feeding Game (adapted from Kirschner & Tomasello, 2010) was used as the main measure of prosocial behavior. The game materials comprised of a small table holding four colored tubes with a small box filled with same-colored balls ("fish food") on it, and a "fish box" distanced 3 m away, which supposedly contained the "hungry fish" that the children needed to feed (see Figure 4). Unbeknownst to the children, they were randomly assigned to "Victim" and "Responder" roles prior to the session. To play the game, the children were instructed to place the balls into color-matched tubes (assigned by *E*) one at a time. When the balls were in the correct tubes, children were instructed to lift the handle that kept the tubes attached to the table and "feed the fish" by carrying the tubes to the fish box and emptying the balls into the box. Children lifted the handle together, which helped to ensure that the children would start carrying their tubes at the same time.

(a) (b)

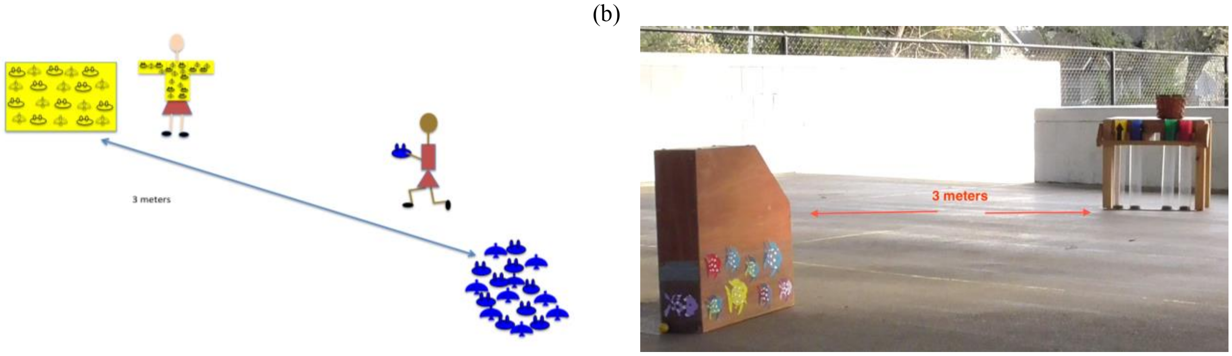


Figure 4. **Experimental setup: (a) Shape game and (b) Fish feeding game.** In the Shape game, all shapes on the board, jacket, and ground were the same size.

The first trial counted as training and took place in the presence of *E*, after which *E* left the room (explaining that she needed to go and check on something). For the second trial, the "Victim" child's tube was set up so that the bottom cap fell off just as the children lifted their tubes to go and feed the fish. Hence, balls in this tube would spill out on the floor, presenting an opportunity for the "Responder" child to help the "Victim" child. The amount of help provided by the Responder was coded post-hoc from the videos and measured as an indicator of prosocial behavior (see Table 2 for coding scheme).

Table 2
Help Categories with Sub-Categories and Descriptions

Category	Subcategory	Description
Y (Yes)	Y1	Helper sees toy break and helps immediately (High Help)
	Y2	Helper does not see toy break, empties own tube, then notices the accident and helps Victim with their tube or balls (Medium Help)
	Y3	Helper sees toy break, empties own tube first, then helps Victim with their tube or balls (Low Help)
N (No)	N1	Helper sees toy break, but does not help Victim at any point (No Help)
	N2	Helper does not see the toy break, empties own tube, then notices the accident, but does not help at any point (No Help)
	N3	Helper only helps at Victim's request, not spontaneously (No Help)

Results

The dichotomous coding of helping versus not helping reflected a pattern in line with our predictions (see Figure 5), although a chi-squared test showed no statistically significant effect of touch condition on helping, χ^2 (1, 84) = 2.58, $p = 0.108$). There was a significant effect of gender on helping behavior, χ^2 (1, 84) = 3.88, $p = 0.048$, with girls, $M = 0.57$, $SD = 0.51$, displaying more help than boys, $M = 0.26$, $SD = 0.45$ (see Figure 5). A binomial logistic regression was conducted to assess whether touch condition predicted dichotomous help categories when controlling for gender; this analysis similarly did not reach statistical significance, 95% CI [0.85, 13.40]. Binomial logistic regression also showed no statistically significant effect of age on helping, 95% CI [-0.07, 0.05].

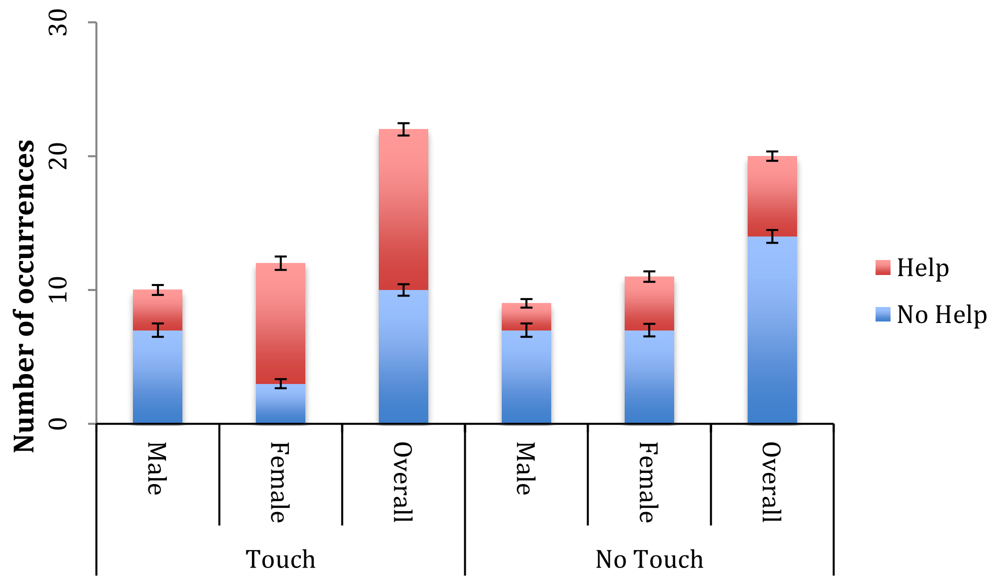


Figure 5. **Frequency of spontaneous helping displayed by the Responder by condition and gender.** Error bars indicate standard deviation (SD).

We conducted an ordinal logistic regression (OLR) to examine the effects of touch, gender, and age on helping levels, which were categorized on a scale from 0 (no help) to 3 (high help). Due to there being zero occurrences of "low help" in the no-touch condition, the proportional odds assumption of the OLR was not met. For this reason, we combined the "low help" and "medium help" categories and conducted OLR using three levels of helping: 0 (no help), 1 (low-medium help), and 2 (high help). In the regression model, help was specified as the ordered outcome variable, age as a continuous predictor variable, and gender and touch were dichotomous predictor variables.

As there was no obvious influence of age on the model (OR = 0.99), it was removed from this model and from further analyses. Proportional odds ratios indicated that the odds of observing high help versus no help and low-medium help combined were 2.64 times greater in the touch than no-touch condition when controlling for gender. However, this effect also did not reach statistical significance, 95% CI [0.76, 10.01].

Gender had a significant effect on level of helping (see Figure 6). As compared to girls, boys were 0.27 times less likely to display high help versus no help and low-medium help combined when controlling for the effects of touch condition, 95% CI [0.07, 0.96]. No interaction effect was found between gender and condition on level of help.

Three separate analyses of self-reported partner liking were conducted: Partner liking reported by the Responder only (scores from 1 to 6), pair-wise liking (average of the two children's reported scores within a pair), and liking similarity (the difference between the two children's reported scores within a pair). No statistically significant effect of condition was found on any of these measures (See Table 3).

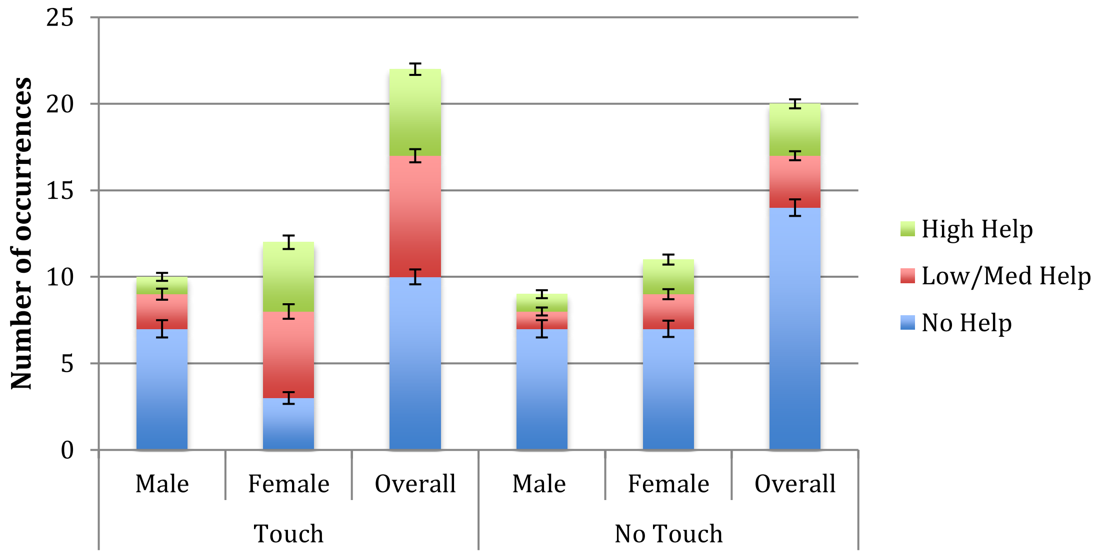


Figure 6. **Helping behavior frequency (3 levels) by condition and gender.** Error bars indicate SD.

Table 3
Mean Liking Scores (SD) with T-test Results for Touch and No-Touch Conditions

	Touch	No-Touch	T-test Results
Responder's reported liking	1.18 (50.00)	1.20 (0.52)	$t(1, 39.22) = 0.11$, $p = 0.909$
Pair-wise reported liking	1.34 (0.64)	1.53 (0.64)	$t(1, 39.68) = 0.93$, $p = 0.358$
Liking similarity	0.59 (1.18)	1.05 (1.28)	$t(1, 38.82) = 1.21$, $p = 0.235$

Discussion

This study sought to explore whether touch that occurs during children's physically active play facilitates prosocial behavior. Our findings did not show a significant effect of touch on helping behavior or interpersonal liking, although the trend was in the expected direction for helping behavior. We also found that, regardless of condition, girls helped each other more than boys; this finding is in line with previous research showing similar gender differences in prosocial behaviors (for a review, see Maccoby, 2002).

One possible reason for the absence of an effect of touch on helping is that touch in the context of our game design was not spontaneous. Previous observational studies have largely focused on how seemingly spontaneous, rather than contrived, touch is related to aspects of social behavior such as generosity (Crusco & Wetzel, 1984; Guéguen, 2004; Guéguen & Jacob, 2005; Hornik, 1992; Kleinke, 1977; Lynn, Le, & Sherwyn, 1998; Stephen & Zweigenhaft, 1986; Ebesu, Tsuji, Williams, & Seatriz 2003), compliance with a request

(Guéguen, 2002; Guéguen & Fischer-Lokou, 2002; Smith, Gier, & Willis, 1982), subsequent positive ratings of the toucher (Erceau & Guéguen, 2007), positive ratings of an experience (Fischer et al., 1976), and spontaneous helping (Goldman & Fordyce, 1983; Paulsell & Goldman, 1984). In contrast, participants in our study not only knew that they would be touched, but they also knew by whom (their partner), why (to apply the shapes into the jacket), and where they would be touched (on the arms and back, where shapes were printed on the jacket). It is possible that touch occurring in such an instructed context does not convey positive interpersonal emotions and attitudes in the same way that spontaneous touch does (Hertenstein et al., 2006; Hertenstein et al., 2009).

Other possible reasons for the null findings may be related to methodological factors, such as sample size and insufficient amount of touch. Due to lack of precedent in the experimental literature on the effects of touch on prosocial behavior, we based our sample size calculation on studies that have used the same helping behavior measure that we used (e.g., following joint music making or synchronous movement). Given that the mean helping behavior trended in favor of our hypothesis, it is possible that a larger sample size and/or increased frequency of touch would provide a more conclusive test of the hypothesis.

General Discussion

The studies reported here examined children's social behaviors in relation to physically active play (Study 1) and experimentally tested the effect of touch on children's prosocial behavior in the context of a physically active game (Study 2). Previous observation systems for children's PA have not quantified touch and prosocial behavior as potential correlates of PA. We found that higher levels of PA and MVHR are related to touch among children engaged in natural play. This supports the view that physically active play is a fertile context for the development of social bonds among children. Study 1 also revealed that girls were more likely than boys to engage in touch and prosocial behavior, a common pattern reported in research on children's prosociality (for a review, see Maccoby, 2002). We also found that both boys and girls smiled and laughed more during activities involving higher level PA than lower level PA, which may indicate increased level of enjoyment. Although self-reported liking and other bonding questions were not included in this observational study, the behavioral findings reported here potentially offer support for the proposed relationship between PA and social bonding; children playing together at higher physical activity levels may enjoy their interactions more and enjoy their time spent together more than children engaged at lower PA levels. Although mechanisms underpinning this association remain largely unknown, this possibility is supported by previous behavioral and neurobiological research which suggests that moderate intensity physical activity facilitates the release of endogenous opioids (Boecker et al., 2008) and endocannabinoids (Raichlen, Foster, Seillier, Giuffrida, & Gerdeman, 2013), which increase positive affect and may influence social bonding (Cohen et al., 2010; Davis et al., 2015; Inagaki et al., 2016; Tarr, Launay, & Dunbar, 2014).

Study 2 developed a novel experimental design to examine the link between touch and prosocial behavior more closely. Results did not support our hypothesis that touch is associated with higher amounts of subsequent prosocial behavior, though there was a non-significant trend of more helping in the touch condition. There was a significant overall gender effect such that girls helped each other more than boys, independent of condition.

Taken together, these results offer novel insights into children's natural play behavior and open up a new area of research into the links between PA and enjoyment, touch, and prosocial behavior. Our hypothesized link between social touch and social bonding in children was motivated in part by research in support of a social bonding function of touch in humans specifically and primates generally (Boone & Buck, 2003; Dunbar, 2010; Feldman et al., 2014; Field, 2010; Fischer et al., 1976; Guéguen & Fischer-Lokou, 2007; Joule & Guéguen, 2007; Light et al., 2005; Seyfarth & Cheney, 2012; Silk, 2007; Silk et al., 2010; Wittig et al., 2008) and of PA and play (Di Bartolomeo & Papa, 2017; Cohen et al., 2010; Inagaki et al., 2016; Macdonald-Wallis et al., 2011; Sanders et al., 2014; Roberts et al., 2013; Rittenhouse et al., 2011). The studies reported here build on this rich empirical context and provide initial evidence of specific links among physically active play, touch, and social bonding in children.

The effects and trends identified in our experimental data can serve to orient further investigation of the relationship between touch and social bonding in children. Although results from Study 1 offer some support for our hypotheses, further studies are needed in order to corroborate these findings. In particular, future observational studies could involve larger sample sizes and multiple independent coders to assess inter-rater reliability. To further assess the associations between PA, touch, and social bonding, observational studies could utilize other measures for social bonding, such as time spent with another individual following touch or MVPA. Due to the infrequency of prosocial and antisocial behavior noted in our observation study, future studies may benefit from staging more structured play activities, in which these specific behaviors would be more likely to occur (e.g., games involving turn-taking or sharing of toys/equipment). By adding this level of control to the observations, the antecedents and consequences of prosocial and antisocial behaviors could be more readily assessed in a naturalistic setting, which could then inform experimental designs.

Study 2 raises questions about the role of touch in children's play and social bonding. For example, how much touch is required to induce positive effects on prosociality? Can instructed touch lead to prosocial behavior, or must touch be accompanied with communicative meaning in order to elicit positive social effects? Previous studies have investigated the effects of seemingly spontaneous touch (from the perspective of the person touched) on spontaneous helping (Goldman & Fordyce, 1983; Paulsell & Goldman, 1984). Future designs could build on the paradigm reported here by adjusting sample sizes, as well as varying the amount of touch and comparing the effects of instructed touch to spontaneous touch on prosocial behavior.

In primary school, children routinely engage in complex social interactions with their peers. Social touch, with its communicative features, may be an important facilitator of social bonds. If touch in physically active play is found to increase social bonding among peers, interventions could be developed to help improve bonding between socially excluded children and others. Touch in physically active play could also have implications for clinical populations, such as children with autism spectrum disorders (ASD). In addition to severe impairments in social interactions, altered sensitivity to sensory stimulation, including tactile stimulation, is a commonly observed symptom that has recently been added to the diagnostic criteria of ASD (American Psychiatric Association, 2013). Studies have found that touch therapy, which typically uses moderate pressure touch, can improve the sleep, touch aversion, social relatedness, and attentiveness of children with ASD (Cullen, Barlow, & Cushway, 2005; Escalona, Field, Singer-Strunck, Cullen, & Hartshorn, 2001; Field et al., 1997). It is possible that identifying optimum amounts, contexts, and pressure levels of touch and integrating this into children's physically active play could be informative for developing interventions that help facilitate social bonding in children with ASD.

More broadly, our finding that PA positively predicts enjoyment (smiling/laughing) is in line with previously reported links between social physical activities and socioemotional and mental health. Previous studies among adolescents suggest that engagement in activities such as team sports is associated with decreased symptoms of depression (Boone & Leadbeter, 2006; Ferron, Narring, Cauderay, & Michaud, 1999;

Gore, Farrell, & Gordon, 2001; Sanders, Field, Miguel, & Kaplan, 2000), increased emotion regulation (Hansen, Larson, & Dworkin, 2003), and less emotional distress (Harrison & Narayan, 2003). In primary school children, sport participation has been suggested as a buffer against social anxiety (Dimech & Seiler, 2011) and is associated with less parent-reported psychological difficulties and fewer internalizing behaviors (Vella, Cliff, Magee, & Okely, 2015). Dance, which often involves MVPA, has also been found to improve social competence and behavioral (internalizing and externalizing) problems among young children (Lobo & Winsler, 2006). Furthermore, there is some evidence suggesting a negative association between mental health and sedentary behavior (Barkley, Salvy, & Roemmich, 2012; Suchert, Hanewinkel, & Isensee, 2015). Taken together, research in this area suggests that joint PA in childhood is an important contributor to children's socioemotional health and development. Integration of physically active play within the school day may be beneficial for primary school children to learn and bond together in ways not previously considered or investigated. This is especially relevant in light of the current trend of diminishing time for traditional recess breaks.

Despite widespread evidence for a social bonding function of touch during infancy and adulthood, and the growing evidence for social bonding effects of collective PA in adults, the social bonding effects of PA and touch among school-aged children have hitherto received very little research attention. The two studies reported here have started to fill this gap by investigating the links between PA, touch, and prosociality in a systematic way using both observational and experimental methods. Future research can help to reveal the role of PA and touch for social bonding in young children and use this knowledge to facilitate outcomes in educational and clinical contexts.

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