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Partner Preference Strength is not Influenced by How Motivated Juvenile Male Rats are to Engage in Play Fighting

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Abstract – Rats frequently engage in rough-and-tumble play, and do so in pairs. However, when multiple partners are present, some individuals are preferred more than others. Rats that have been isolated from their peers show increased motivation to engage in rough-and-tumble play. When publishing papers on group play in rats, we have been asked by several reviewers whether the time spent in social isolation to increase play motivation inadvertently reduces partner preferences. To address this question, we investigated how varying periods of social isolation (0, 2.5, E. J. Marijke Achterberg[2]12, and 24 h) influences partner preferences of focal Long Evans rats when interacting with one unfamiliar Long Evans partner and one unfamiliar Fischer 344 partner. Regardless of the degree to which the rats were motivated to play, partner preferences remained stable across isolation times. This suggests that the general drive to play is independent of the motivation to select a specific partner. Unexpectedly, the preference for same-strain partners was not as strong as in previous studies with larger groups, highlighting that group size and social context are critical factors that can alter social dynamics and potentially override established partner preferences. These findings underscore the importance of group composition in the study of social behavior and suggest that partner preferences may reflect stable social compatibilities rather than transient changes in play motivation.

Keywords – *Rattus norvegicus*, Rough-and-tumble play, Social behavior, Social isolation, Social play

Of the many forms of play behavior present in mammals (Burghardt, 2005; Fagen, 1981; Pellis & Pellis, 2009), rough-and-tumble play (RTP), or play fighting, is the most common form of play reported and studied (Pellis et al., 2024; Pellis & Pellis, 1998). Regardless of the species, when animals engage in RTP they compete for an advantage over their partner (e.g., access to a particular location on the partner's body), but this competition is coupled with cooperation, ensuring the play is reciprocal to some degree (Aldis, 1975; Palagi et al., 2016, 2024). Though a variety of animals engage in RTP (Burghardt, 2005; Fagen, 1981; Pellis & Pellis, 2009), the laboratory rat (*Rattus norvegicus*) has been the most intensively studied species, providing many insights into its neurobiology and developmental consequences (Achterberg & Vanderschuren, 2023; Pellis et al., 2023; VanRyzin et al., 2020a). For example, in several species, including humans, play has been shown to have positive effects on the development of executive function and its underlying neural mechanism (Baarendse et al., 2013; Bijlsma et al., 2022; Diamond et al.,

2007; Ham et al., 2024; Marks et al., 2017; Nijhof et al., 2018) as well as broader social and affective processes (Panksepp & Yovell, 2014; Pellis et al., 2025; Pellis & Pellis, 2009).

Rats of all ages engage in RTP, although its occurrence peaks during the juvenile period (Panksepp, 1981; Pellis & Pellis, 1990; Thor & Holloway, 1984). Regardless of age, rats attack and defend the nape of the neck during RTP, which, if contacted, is gently nuzzled with the snout (Pellis & Pellis, 1987; Siviy & Panksepp, 1987). Typically, 80% or more of the nape attacks launched are defended by the recipient, and to do so they can use several different tactical maneuvers (Himmler, Pellis, et al., 2013; Pellis et al., 2022). All rat strains, including wild rats, mostly attack and defend the nape and use the same suite of defensive tactics, although the frequency of nape attacks and the preferred tactics used can vary (Himmler, Stryjek, et al., 2013; Himmler et al., 2014; Orsucci et al., 2025; Siviy, 2020).

While RTP in rats is typically tested in dyads (Himmler, Pellis, et al., 2013; Pellis et al., 2022; VanRyzin et al., 2020b), we have recently started testing rats in small groups (3 or more individuals) (Ham et al., 2025, 2026a, 2026b; Ham & Pellis, 2023, 2024, 2025) as this more accurately reflects the context in which rats would play in the wild (Pellis et al., 2022, 2023). Typically, wild rats live in colonies with multiple breeding females, consequently, juveniles would have access to many play partners, both littermates and those from neighbouring litters (Calhoun, 1963; Schweinfurth, 2020). When tested in groups, rats form partner preferences, launching more nape attacks towards some individuals than others (Ham & Pellis, 2023, 2024, 2025; Holman et al., 2019). Because rats naturally engage in RTP with their cage mates throughout the day (Meaney & Stewart, 1981), it is common practice to socially isolate the rats before testing RTP play (Himmler, Pellis, et al., 2013; Pellis et al., 2022). This brief period of isolation increases their motivation to play, with longer isolation durations producing greater increases in the frequency of nape attacks (Panksepp & Beatty, 1980; Pellis et al., 1997; Siviy et al., 1997). Isolation ensures that the rats have not recently engaged in play within the home cage and are therefore not play-satiated at the start of testing. Therefore, we also subjected rats to a brief period of social isolation period prior to testing their play when in a group (Ham et al., 2025; Ham & Pellis, 2023, 2024, 2025). However, as we reported a significant, but modest degree of partner preferences in these studies, several reviewers wondered whether the time spent in social isolation reduces partner preferences. That is, the hypothesis may be posited that increasing the motivation to engage in play interferes with partner preferences because the drive to play overrides partner preferences. If so, the commonly used practice of isolating rats to increase play motivation could inadvertently alter the social dynamics being measured, complicating the interpretation of partner preference studies of group play.

To test whether the degree of motivation to engage in RTP influences partner selection, we examined trios of juvenile male rats, that were unfamiliar with one another, after subjecting them to different periods of isolation. Given that our previous findings revealed that when tested in groups of four, Long Evans (LE) rats prefer same-strain partners over Sprague Dawley and Fischer 344 (F344) rats (Ham et al., 2025), the focal LE rats in the present study were tested with two partners: one LE and one F344 partner. F344 rats were selected as the alternative strain because they exhibit more pronounced differences from LE rats in both the frequency and structure of play (Ham et al., 2025; S. M. Himmler et al., 2014; Schneider et al., 2016; Siviy et al., 1997, 2003, 2023). These characteristics make them a less compatible play partner and therefore provide a stronger test of strain-based partner preference than strains such as Sprague Dawley, which are more similar to LEs in play style and frequency (Ham et al., 2025). Triads were used so that the focal rat had a direct choice between two simultaneously available partners while minimizing the additional social complexity present in larger groups. Therefore, to increase the strength of partner preference, each trio consisted of two LE rats and one F344 rat. One of the LE rats from each triad was selected as the focal rat and the number of nape attacks it directed toward each of its group members following 0, 2.5, 12, and 24 h of social isolation was quantified. These durations were selected based on previous studies showing that increasing the length of social isolation increases the frequency of RTP, with motivation rising rapidly during the first few hours and approaching a plateau between approximately 12 and 24 h of isolation (Panksepp & Beatty, 1980; Pellis et al., 1997). Thus, these isolation times allowed us to sample a range of play motivation from minimal (0 h) to near-maximal levels (24 h). Based on previous studies, it was predicted that increased isolation time would increase the number of nape attacks launched

(Pellis et al., 1997). In contrast, the novel hypothesis tested in this paper predicts that higher levels of motivation should reduce the strength of partner preferences exhibited.

Methods

Ethics statement

All care and testing procedures were approved by the University of Lethbridge Animal Welfare Committee (Protocol #2408) in compliance with guidelines from the Canadian Council for Animal Care.

Subjects

Sixteen Long Evans (LE) and eight Fischer 344 (F344) male rats were purchased from Charles River Laboratories. They arrived at the Canadian Centre for Behavioural Neuroscience at 22-23 days of age. Upon arrival, the rats were housed in same-strain pairs. The rats were housed in double-decker cages (Tecniplast® GR1800) with corncob bedding. Food and water were provided *ad libitum*. Animals were housed on a 12 h light-dark cycle with the lights on between 0730 and 1930 in a room maintained at a constant temperature of 21-23ºC.

Only males were used so that all play groups were composed of individuals of the same sex. Previous work from our laboratory has shown that juvenile male and female rats engage in similar levels of RTP when tested in same-sex trios (Ham et al., 2026b). Therefore, restricting testing to males ensured that partner preferences were not influenced by sex-related social interactions. Future studies should examine whether similar patterns occur in females.

Apparatus

Play testing was conducted in a clear Plexiglas enclosure (80 × 80 × 50 cm). The floor of the enclosure was covered with around 3 cm of corncob bedding (Pellis et al., 2022). Play sessions were filmed with a digital video camera (Sony Handycam FDR-AX53) which was placed over the enclosure at a 90º angle. To illuminate the enclosure, red lights were used.

Procedure

At 27 days of age, the rats were habituated to the test enclosure for 10 minutes, with their cage mates, in red light (Pellis et al., 2022). This was repeated for three consecutive days between 0730 and 1200. At 30 days of age testing began. Before each test session, rats were weighed and their tails marked with a permanent marker pen (Sharpie®).

Eight of the 16 LE rats were designated as the ‘focal’ rats and were the primary subjects of this study. LE rats were used as focal subjects because the experimental design required that the focal rat have a choice between a same-strain and a different-strain partner. In the triads used here (LE + LE + F344), only LE rats had access to both a same-strain and different-strain partner. To determine if isolation time affected partner preference strength, rats were tested after four different isolation times. Rats were (a) not isolated, (b) isolated for 2.5 h, (c) isolated for 12 h, or (d) isolated for 24 h. Each focal rat underwent all four isolation conditions. Isolation conditions were counterbalanced so that two focal rats on test day one, were not isolated, two were isolated for 2.5 h, two for 12 h, and finally, two for 24 h. On the following test day, the isolation condition was rotated so that each rat underwent a new isolation condition. All rats within a group that were tested together underwent the same isolation procedure. The same isolation condition was not repeated for any of the animals. When socially isolated, rats were held in decker cages and had food and water provided *ad libitum*.

Rat play was tested in groups of three, with each consisting of a focal LE rat, a partner LE rat, and a partner F344 rat. Triads were used so that the focal rat had a direct binary choice between two

simultaneously available partners, allowing the strength of partner preference to be quantified while minimizing additional social complexity that would arise in larger groups. Rats were always tested with individuals with which they were not familiar. That is, all triads were composed of strangers. Following one of the four isolation conditions, rats were placed into the test enclosure, in red light, for 20 min and the trial was recorded using a digital video camera. Following test sessions, the rats were placed back into their respective home cages. Testing was repeated for four days so that each focal rat underwent all four isolation conditions. A rest day was provided in between each test day to ensure that they were socially housed for 24 h before starting the next round of isolation.

Behavioral analysis

Once the play testing was completed, the videos were analyzed using a combination of normal speed and frame-by-frame analysis to score behavior (Himmler, Pellis, et al., 2013; Pellis et al., 2022). As we were interested in how a focal rat would distribute its play among the potential play partners, we used a focal follow approach (Bateson & Martin, 2021) and scored the distribution of nape attacks directed at each partner. Playful attacks were scored when the snout of one rat was in contact with, or directed towards, the nape of another rat (Pellis et al., 2022).

Statistical analyses

All statistics and plots were done using Prism version 10 (GraphPad Software).

To determine if rats engaged in more play following increased isolation time, Friedman tests were used as the data did not meet the assumptions of normality (Shapiro-Wilk: $p < .05$). When significant, *post hoc* evaluations of the data were conducted using a Dunn's multiple comparisons tests.

If the rats did not form preferences, both partners should receive around 50% of the total nape attacks launched by the focal subjects. Using single sample t-tests, we tested whether the focal rats directed significantly more than 50% of their play to the preferred partner for each of the isolation times (0, 2.5, 12, and 24 h). The preferred partner was identified as the one that was attacked more often, regardless of strain. After determining if rats expressed partner preferences, comparisons of the strain that was preferred were made by calculating the percentage difference in nape attacks between F344 and LE partner rats:

$$\frac{LE\ attacks - F344\ attacks}{LE\ attacks + F344\ attacks} \times 100$$

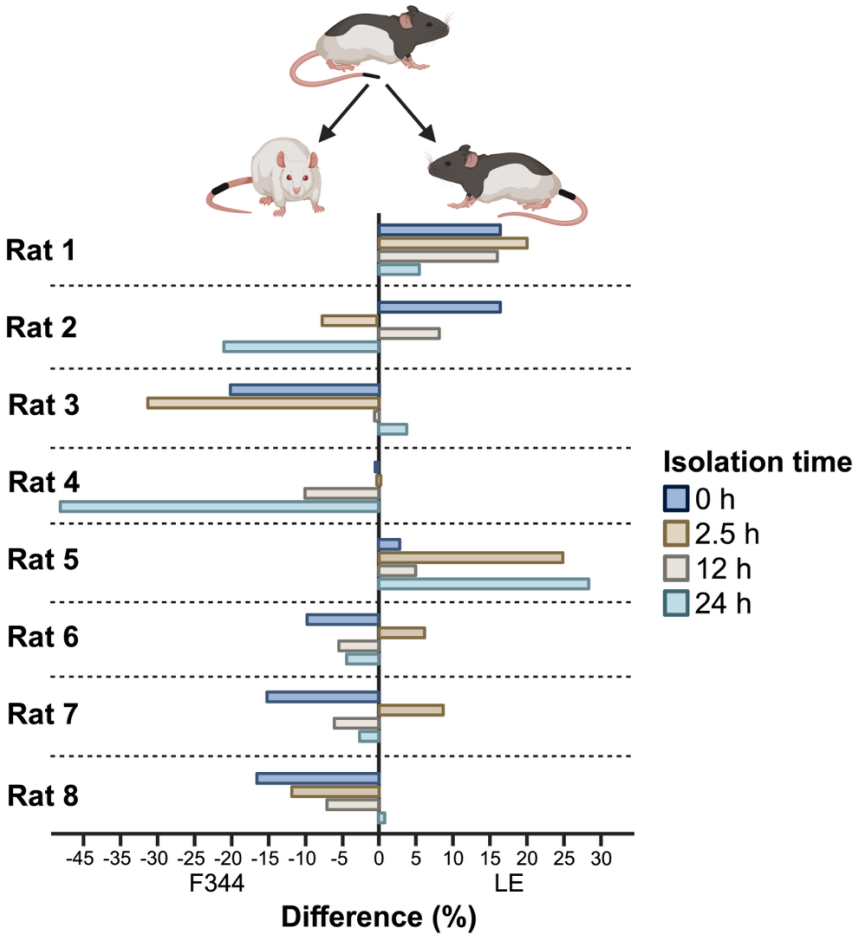
Negative percentages indicate that F344 rats were attacked more frequently, whereas positive percentages indicate that LE rats were attacked more. In addition, we used Friedman tests to determine if same-strain partners were attacked more than F344 partners.

Results

LE rats played with both LE and F344 partners, with some rats consistently preferring LE partners (e.g., Rat 1), others preferring F344 partners (e.g., Rat 4), and yet others switching between LE and F344 partners (e.g., Rat 2) (Figure 1). The focal LE rats did not show a significant preference for the same strain partners ($p > .05$). Nonetheless, as shown below, they did exhibit a preference for one partner over the other, enabling us to test the main prediction.

Figure 1

The Percentage Difference in Nape Attacks Focal LE Rats Directed Towards F344 (Left) And LE Rats (Right) Following 0 h, 2.5 h, 12 h, and 24 h Isolation

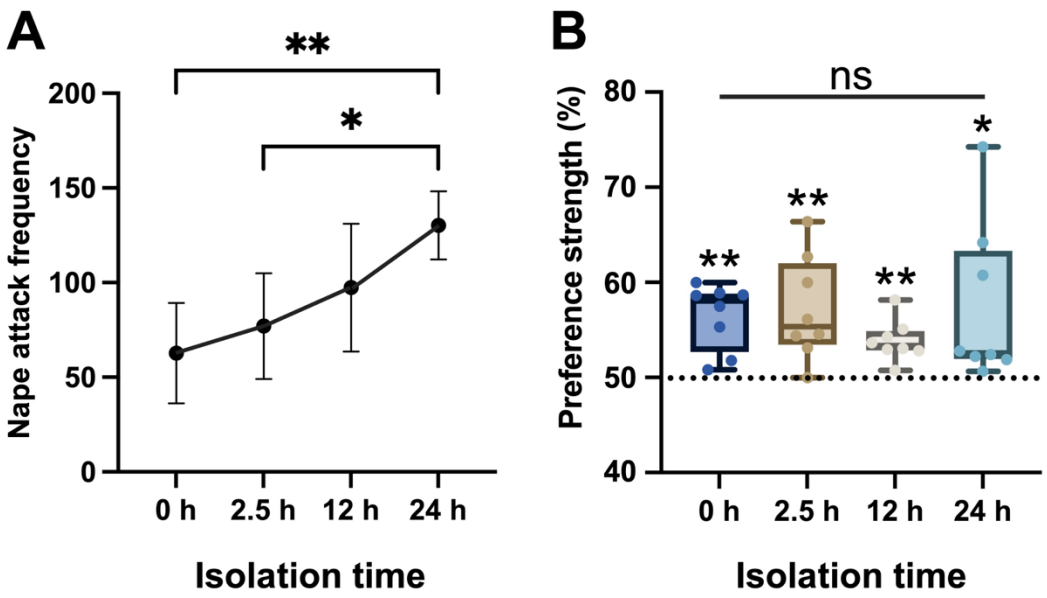


Note. Made with BioRender.com.

As expected, the number of nape attacks launched by the focal LE rats increased significantly with length of time isolated ($X^2(3) = 15.45$, $p = .0015$). Post-hoc tests showed that LE rats launched more attacks following 24 h isolation compared to 0 h and 2.5 h but did not differ from 12 h. Similarly, 0 and 2.5 h did not differ significantly from one another (Figure 2A). The focal LE rats directed significantly more than 50% of their play to one of their partners at all isolation times (0 h: $t(7) = 5.266$, $p = .0012$; 2.5 h: $t(7) = 3.723$, $p = .0074$; 12 h: $t(7) = 5.055$, $p = .0015$; 24 h: $t(7) = 2.498$, $p = .0411$). The magnitude of these preferences was moderate to large across isolation times (Cohen's d = 1.86, 1.32, 1.79, and 0.88 for 0 h, 2.5 h, 12 h, and 24 h isolation, respectively. However, the strength of the preference or the percentage of play directed towards the preferred partner did not differ significantly with isolation time ($X^2(3) = 4.050$, $p = .256$) (Figure 2B).

Figure 2

Effects of Isolation Duration on Play Initiation and Partner Preference Strength in Rats



Note. (A) The total number of nape attacks initiated by the focal rat was significantly greater following 24 h isolation compared to 0 h and 2.5 h isolation. Data are presented as mean ± the standard deviation. (B) Rats directed significantly more of their play towards one partner than would be expected if the focal rat had attacked each partner equally. Significant differences are indicated by asterisks. However, there was no significant difference in preference strength across the four time points, suggesting that isolation time did not affect partner preferences. Data are presented as mean ± minimum to maximum. *$p < .05$, **$p < .01$

Discussion

When isolated from their peers, juvenile rats become more motivated to engage in RTP (Niesink & Van Ree, 1982; Panksepp & Beatty, 1980; Pellis et al., 1997; Siviy et al., 1997), a finding that was replicated in the present study (Figure 2A). However, the strength of partner preference did not change with increased motivation to play (Figure 2B), thus not supporting the hypothesis that motivation to play interferes with forming play partner preferences. Rather, the present results support an alternative hypothesis that the motivation to play and the motivation to interact with particular partners involve independent mechanisms. Studies have shown that distinct brain regions can be manipulated to increase or decrease play behavior while leaving the level of general social behavior (e.g., social investigation) unchanged (e.g., Achterberg et al., 2015; Nyberg et al., 2025; Veenema et al., 2013), supporting the likelihood that interest in certain individuals may involve different neural mechanisms.

Moreover, the present findings are consistent with our previous studies in showing that the magnitude of partner preference is mild to moderate (see Ham et al., 2025, 2026b; Ham & Pellis, 2023, 2024, 2025). That is, rats form significant, but weak partner preferences when given a choice of partners, with the choice influenced by many different factors (e.g., degree of familiarity, dominance, congruence in play style, sex of partners) depending on group composition. A yet to be resolved problem is why rats continue to play with less preferred partners when the preferred ones are available (e.g., Ham et al., 2025, 2026c; Ham & Pellis, 2023).

Because our analysis focused on the distribution of nape attacks initiated by the focal rat, we did not quantify how often partners initiated play toward the focal individual. It is therefore possible that partner preferences were influenced not only by the focal rat's behavior but also by differences in how frequently partners attempted to initiate play (Ham & Pellis, 2024). Examining the bidirectional play initiation would help determine whether partner preferences emerge primarily from the focal animal's choice or from

reciprocal interaction dynamics between partners. Future work examining bidirectional interactions will be important for disentangling partner preference from differences in responsiveness across strains.

Two's Company, Three's a Crowd

The present study also raises another important methodological issue that should be considered in future studies of partner preference. To our surprise, the focal LE rats did not develop a strong preference for same strain partners. In a recent experiment, using a similar methodology, we found that juvenile male LE rats prefer same strain partners when playing in groups where they had the choice between an LE, Sprague Dawley, and an F344 partner (Ham et al., 2025). In that study, LE rats played with same strain partners around 60% of the time, directing only 20% of their play towards Sprague Dawley partners and 20% towards F344 partners. Given this robust effect, we expected the LE rats to show an even stronger preference for same strain partners, since there were fewer partners from which to choose. This was not the case, as either rat could be the preferred partner in each test session (Figure 1).

Because only LE rats served as focal subjects, it is also possible that the observed patterns of partner preference reflect strain-specific characteristics. F344 rats are generally less playful than LE rats (Siviy, 2020); however, they play considerably more when paired with same-strain partners (Ham et al., 2024). In contrast, LE rats do not substantially change how much they play when paired with same- or different-strain partners (Ham et al., 2025). If tested as focal subjects, F344 rats might therefore exhibit different or possibly stronger patterns of partner selection.

Upon closer examination of the recorded video sessions, we observed that the rats behaved differently in trios (present study) compared to quads (Ham et al., 2025). In the quads, when the focal LE played with the other LE, the F344 and Sprague Dawley typically played together, forming two sub-groups. In contrast, in the trios, when two animals were engaged in play, the third was left out, in which case, the "third" rat was often observed inserting himself into the ongoing play bout. When this occurred, one of the two in the dyad often stopped playing and instead attacked the "loner" rat. In the quads, the tendency for LE rats to preferentially engage with same-strain partners appeared to contribute to the emergence of sub-group structure, with interactions often partitioning into two smaller units. However, given the reciprocal nature of play (Pellis et al., 2024), these patterns likely reflect the combined interaction dynamics of all animals involved, rather than being driven solely by LE preferences. In contrast, in the trios this division was not possible.

These observations highlight that triadic interactions are qualitatively different from quadratic ones and raise an important methodological consideration: how many rats should be used when testing group play? Group size is known to influence social dynamics across many species, as the number of available interaction partners can alter patterns of competition, cooperation, and partner choice. For example, studies in rats have shown that prosocial behavior differs between dyadic and triadic interactions (Winokur et al., 2023), suggesting that even small changes in group composition can reshape social structure. More broadly, similar effects of group size on interaction patterns have been reported in a variety of social animals, where the presence of additional individuals can disrupt or redirect ongoing interactions. In our study, the instability of trios also appeared to undermine stable partner preferences, producing more fluid and often disrupted social dynamics. Given our present state of knowledge about group dynamics regarding play, unless there are strong reasons for using triads (Achterberg et al., 2024), we recommend using groups of four or six (Ham & Pellis, 2023, 2024, 2025) to study partner preferences. Larger groups provide a richer social structure and the opportunity to form stable subgroups (Ham & Pellis, 2024, 2025).

Conclusion

In summary, our results demonstrate that while social isolation reliably increases the frequency of RTP in juvenile male LE rats as previously shown (Panksepp & Beatty, 1980; Pellis et al., 1997; Siviy et al., 1997), it does not alter the strength of their partner preferences. Even when highly motivated to play, focal rats had a preference for one of their partners, suggesting that the drive to play is distinct from the

drive to select a particular partner. However, group composition and size emerged as important methodological factors, with trios producing more fluid and less polarized social interactions than previously observed in groups of four. These findings underscore the importance of considering social context when designing group play studies and highlight that partner selection may reflect more enduring social or strain-based compatibilities rather than transient changes in play motivation.

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Data Availability: The datasets supporting this article have been uploaded to figshare and are publicly available:https://figshare.com/articles/dataset/Data_from_Partner_preference_strength_is_not_influenced_by_how_motivated_juvenile_male_rats_are_to_engage_in_play_fighting_/34264335

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