Social integration of new individuals to stable social groups

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ABSTRACT

Social integration is the process by which individuals are accepted into a new group and establish social relationships with its members. Despite the importance of social integration, especially during dispersal, research has mostly focused on studying the implications and costs of dispersal decisions but the strategies that individuals use to successfully integrate into the new group are still unclear. Specifically, I aimed to assess whether a new individual initiates more interactions with the dominant member (*befriend the dominant hypothesis*), and whether possessing novel knowledge accelerates social integration (*knowledgeable individual hypothesis*). To do this, I used 16 female guinea pigs distributed in four enclosures. The experiment consisted of adding a new individual to an already established group of three individuals, for which the dominance hierarchy was previously established through a food allocation test. For the treatment condition a knowledgeable individual trained in a foraging task was introduced, while in the control condition a naïve individual was added. There were two replicas per condition. The results suggest that social integration is divided in three phases as proposed by Kohn (2019): exploration (the new individual exhibits affiliative interactions towards the others), pruning (affiliative and aggressive interactions within the group increase due to behavioral feedback) and consolidation (formation of longer-lasting relationships). I did not find support for the *befriend the dominant hypothesis* or the *knowledgeable individual hypothesis*. This suggests that the strategies for social integration in guinea pigs differ from those observed in primates. Overall, this study highlights the need for further exploration and understanding of the unique dynamics behind social integration in other animal groups that have been less studied.

RESUMEN

La integración social es el proceso mediante el cual los individuos son aceptados en un nuevo grupo y establecen relaciones sociales con sus miembros. A pesar de la importancia de la integración social, especialmente durante la dispersión, las investigaciones actuales se han centrado principalmente en estudiar las implicaciones y los costos de las decisiones de dispersión, pero las estrategias que utilizan los individuos para integrarse con éxito en el nuevo grupo aún no son claras. Específicamente, mi objetivo era evaluar si un nuevo individuo inicia más interacciones con el miembro dominante (*hipótesis de amistad con la dominante*), y si poseer conocimientos novedosos acelera la integración social (*hipótesis del individuo conocedor*). Para ello utilicé 16 cobayas hembras distribuidas en cuatro encierros. El experimento consistió en agregar un nuevo individuo a un grupo ya establecido de tres individuos, para los cuales la jerarquía de dominancia se había establecido previamente mediante una prueba de asignación de alimentos. Para la condición de tratamiento se introdujo un individuo experto y entrenado en una tarea de búsqueda de alimento, mientras que en la condición de control se agregó un individuo sin experiencia. Hubo dos réplicas por condición. Los resultados sugieren que la integración social se divide en tres fases como propone Kohn (2019): exploración (el nuevo individuo exhibe interacciones afiliativas hacia los demás), filtración (las interacciones afiliativas y agresivas dentro del grupo aumentan debido a la realimentación conductual) y consolidación (formación de relaciones más duraderas). No encontré apoyo para la *hipótesis de amistad con la dominante* ni para la *hipótesis del individuo conocedor*. Esto puede indicar que las estrategias de integración social en cobayas difieren de las observadas en primates. En general, este estudio destaca la necesidad de una mayor exploración y comprensión de la dinámica única detrás de la integración social en otros grupos de animales que han sido menos estudiados.

KEYWORDS

Dispersal, Dominance hierarchy, Social instability, Social networks, Learning curve.

PALABRAS CLAVE

Dispersión, Jerarquía de dominancia, Inestabilidad social, Redes sociales, Curva de Aprendizaje.

1. INTRODUCTION

Social integration, the process by which individuals are accepted into a new group and establish social relationships with its members (Beresnevièiûtë, 2003; Petersen et al., 1989), plays a pivotal role in life history stages such as dispersal. During the last stage of animal dispersal, immigration, the dispersing individuals from group living species must join a new group (Figure 1A). Because dispersal entails a cost (Bowler & Benton, 2005; Cant et al., 2001; Howard, 1960), individuals need to maximize their chances of being accepted and form stable social bonds with members of the new social group (Armansin et al., 2020; Cheney & Seyfarth, 1983). Successfully integrating into a new group represents a benefit to the individual. For instance, in feral horses (*Equus caballus*), unrelated females that can successfully integrate into a group experience an increase in foal birth rates and survival rates compared to the non-integrated ones (Cameron et al., 2009). Also, in humans, social integration reduces mortality risks and improves mental health (Seeman, 1996). These suggest that individuals may have social strategies to facilitate this process. However, how individuals are integrated into the new group or the strategies they use is still unclear.

It has been proposed that the process by which individuals integrate into a group comprises three differentiated stages (Kohn, 2019). First, the new individual explores its social environment, exhibiting affiliative interactions towards the members of the new group (i.e. Exploration). Second, the rate of affiliative and aggressive interactions within the group increases in response to contingent behavioral feedback from others (i.e. Consolidation). Third, the formation of long-lasting relationships (i.e. Pruning). Although this model is very clear, it was proposed to explain how a juvenile that did not disperse develops its social relationships within its natal group, thus it has yet to prove its validity in the context of animal dispersal. Moreover, the process itself may be accompanied by strategies newcomers use to ease integration, but these have yet to be explored.

When individuals integrate into a new stable social group, behaviors such as grooming can facilitate the development of social relationships (Pfalzer & Ehret, 1995), especially in structured groups with dominance hierarchies. In this regard, the social grooming model posits that adult female monkeys groom high-ranking individuals more compared to low-ranking individuals (Seyfarth, 1977). This preference is an attempt to recruit a dominant ally in an agonistic context (Seyfarth, 1977, 1980), such as the one faced when joining a new group. Indeed, in Bonobos (*Pan paniscus*) immigrant females tend to groom high-ranking females more than middle- and low-ranking females (Toda & Furuichi, 2022). Given that grooming serves to develop and/or reinforce social bonds (Kutsukake & Clutton-Brock, 2006; Matheson & Bernstein, 2000), I capitalize on the dynamics of affiliative and aggressive interactions between the new individual and the established group to propose the *befriend the dominant hypothesis* to explain the process of integration of adult individuals. Under this hypothesis, the new individual will initiate more interactions with the dominant individual of the stable group. This will result in forming a stronger social bond compared to the ones formed with the other individuals at the start of the integration (i.e. the exploration phase; Figure 1B). Hence, I expect for the new individual to show a biased number of interactions towards the dominant female during pruning, strengthening that connection. But in consolidation, the bonds between the new individual and the rest of the group will continue to develop for a complete integration.

Knowledge, specially the one that dispersing individuals may possess and that the established group does not have, may facilitate the process of social integration. Knowledge could confer an advantage to the new individual that may ease the integration process by influencing the dynamics of social interactions. In fact, it has been shown that in *Lemur catta*, *Corvus corax*, and *Macaca* *fascicularis*, knowledgeable individuals receive more affiliative behaviors and become more central in the social network (Kulahci et al., 2016, 2018; Stammbach, 1988), highlighting how novel knowledge can enter a population though individuals and change its social dynamics. Based on this, I propose a second hypothesis, *the knowledgeable individual hypothesis*. Under this hypothesis, the new and knowledgeable individual will receive affiliative interactions from other members of the established group in a more even pattern. Moreover, aggressive behaviors will be less frequent in comparison to affiliative ones during the initial phases (exploration and pruning), leading to the formation of a more cohesive group and speeding up the integration process (Figure 1B). In this case, I expect the new individual to receive more affiliative interactions from the group members during pruning, although a preferential relationship with the dominant individual may or may not develop. For the consolidation phase, the time it takes for integration is shorter than under the first hypothesis (Figure 1B).

Here I aim to test Kohn's (2019) framework within the dispersal context and evaluate the proposed hypotheses using guinea pigs (*Cavia porcellus*), a caviomorph rodent, as a study system. Guinea pigs are a good candidate to investigate these hypotheses because they live in harem groups generally composed of 2-3 females with one male (Asher et al., 2004), which undergo changes in composition over time due to dispersal, predation and immigration (Asher et al., 2008). Females live in stable groups that are organized in linear dominance hierarchies (Sachser, 1998; Thyen & Hendrichs, 1990). Furthermore, guinea pigs can learn by association based on visual cues (Braveman, 1974; Lichtenstein & Cassini, 2001), and can learn through interactions with conspecifics (Monfils & Agee, 2019), characteristics that are key for exploring the second hypothesis.

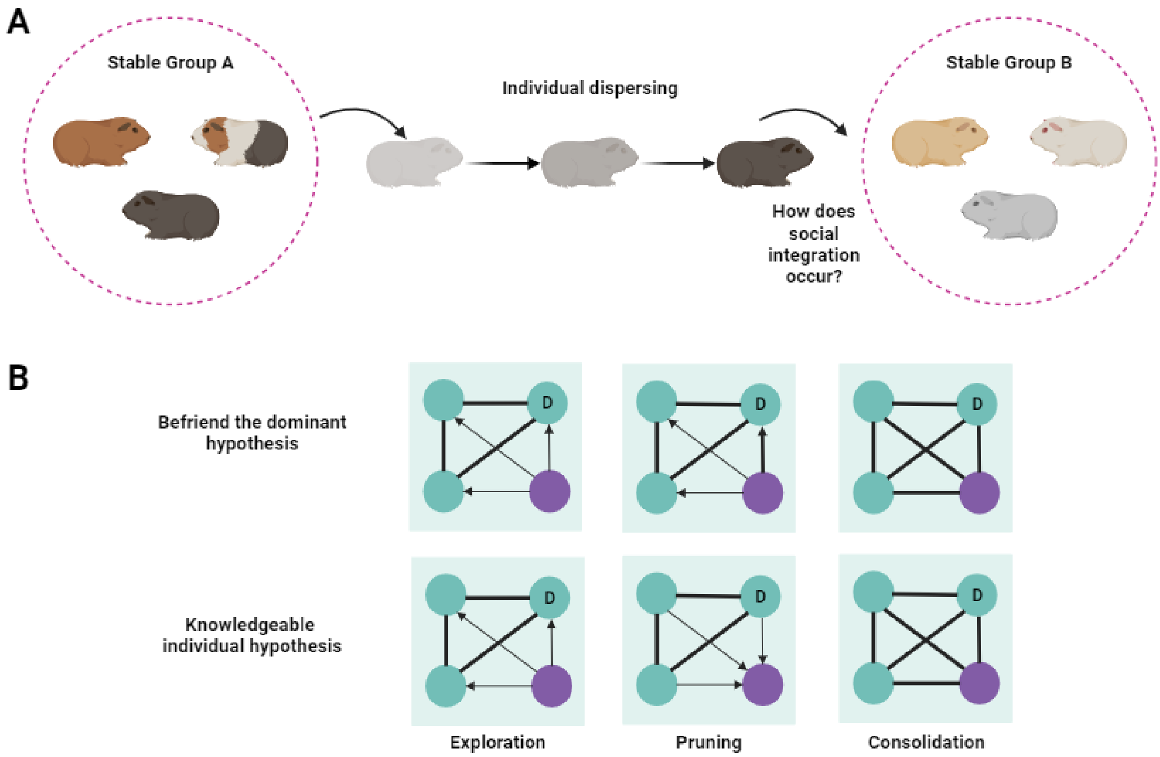

Figure 1. A. Schematic representation of the process of animal dispersal. The individual in the gray outside the circles is dispersing from the stable group A and aiming to integrate into the stable group B. **B.** Expected social networks for each hypothesis. During exploration the new individual exhibits affiliative interactions towards the others. Throughout pruning, in the case of the *befriend the dominant hypothesis* the new individual shows a biased number of interactions towards the dominant (arrows) compared to the other individuals in the group. Meanwhile for the *knowledgeable individual hypothesis*, the new and knowledgeable individual will receive (arrows) affiliative interactions from other members. Finally, in consolidation the social bonds between the new individual and the rest of the group strengthen although this would start occurring faster for the *knowledgeable individual hypothesis*. Dots indicate individuals from an already established group (blue), new (purple) and dominant (marked with a D). Some of the

dyads in the already stable group have developed stronger social bonds (thicker lines) compared to other dyads (thinner lines).

2. MATERIALS AND METHODS

2.1 Study system

The study was carried out with 16 captive-bred adult females sourced from a breeder in Bogota, Colombia, 12 of which were previously acquired and lived in four stable groups of three individuals each. The remaining four individuals correspond to the novel individuals. All of the guinea pigs were adults to avoid any developmental changes in social behavior (Trillmich et al., 2007). Individuals were uniquely marked with hair dye, and each group was housed in a 1.2 m x 1.5 m pen, following the minimum space required for guinea pigs (Willis et al., 1977), that was enriched with a house, PVC tubes for hiding and sticks for chewing. Food (hay and alfalfa pellets), and water was provided *ad libitum* on a weekly base. The diet was supplemented with fresh vegetables on a weekly base.

2.2 Dominance hierarchy

To determine the hierarchical structure in each of the established groups, I conducted a food allocation test (modified after Schweinfurth et al., 2017) where I set two out of the three individuals of each group in an empty enclosure with a highly palatable food item (broccoli) placed in a plate equidistantly from each individual (Figure S1). The winner of the encounter was defined as the one that monopolized the broccoli for a longer period of time in comparison to the companion. All of the possible dyads from each of the three member groups underwent the test. Each dyad was tested four different times (four replicas). Individuals only had access to water and hay, but not pellets, before the test to increase the motivation level to acquire the reward.

2.3 Foraging task training

The focal individuals (i.e., the ones that were introduced to the groups) were exposed to a puzzle foraging device (Figure S2) that allowed controlling the access to a food reward, alfalfa cubes (Ojima & Horikawa, 2016). To access the reward, individuals had to press down onto a platform using the strength of their paws or head. Three individuals were trained on the device to ensure that at least two learned the task. Each individual was exposed to the foraging device for 30 minutes per day (Figure S3) for a maximum training period of fifteen days. For each session, I recorded the amount of rewarded and non-rewarded trials per individual and produced a learning curve (Figure S4) to determine if they learned the task.

2.4 Data collection

The study consisted of two phases: pre-treatment with a duration of two weeks, and treatment the following next four weeks (Figure S3). During pre-treatment, I characterized the social relationships of each of the four previously established groups (i.e., stable groups). During the treatment phase, the new individuals were randomly assigned to one of the four established social groups as two were trained in the foraging task beforehand (knowledgeable individual; treatment), and two individuals were naïve to the task (naïve individual; control).

In each phase, I monitored both affiliative and aggressive behaviors between all pairs of individuals within each group using a continuous sampling scheme on all individuals. Affiliative behaviors include social foraging, sitting in body contact, sitting in close proximity and grooming. Aggressive interactions include biting, chasing, and leaping attacks like wrestling and pounce (Wagner, 2014). For each behavior, I recorded the number of times it was observed (in the case of events) and the duration of its occurrence (in the case of states). Observations took place early in the morning for a period of four hours and before individuals were regularly fed with alfalfa pellets. This means that the only source of high-quality food was the puzzle box.

2.4.1 Dominance hierarchy

I first characterized the dominance hierarchy of each group. For this, I used the dyadic aggressive interactions to construct a winner-loser matrix and estimated the dominance rank of all individuals within the group during the pre-treatment phase. I employed both David's score and randomized Elo-rating for ranking comparison as these methods are considered optimal when hierarchies are not extremely steep (Sánchez-Tójar et al., 2018). Both methods yielded consistent results, with the exception of two individuals in group 1 with a similar hierarchy (Table S1). To address this, I opted for the original Elo-rating that is able to establish a clear linear hierarchy with small sample sizes (Neumann et al., 2011). Dominance scores and ranks were obtained using the 'aniDom' (Sanchez-Tojar, 2021) and 'EloRating' (Neumann & Kulik, 2020) packages.

2.4.2 Social dynamics

For the assessment of changes in the social dynamics I created weighted and directed social networks for affiliative and aggressive behaviors for each group at each phase of the experiment using the 'igraph' package (Csárdi et al., 2024). First, I estimated the total duration of the affiliative behaviors and the number of aggressive interactions initiated and received by each individual before and after the introduction of the new individual. Then, I calculated the rates of interaction by dividing the total number of aggressive interactions — or, in the case of affiliative behaviors, using the total duration of the interactions— by the sampling effort (total hours of video) (Whitehead, 2008). Next, I built social networks for each group for both, aggressive and affiliative behaviors in the pretreatment and the treatment. In each network, the nodes represent an individual and the edges correspond to the interaction rates calculated for affiliative and aggressive behaviors.

To describe the process of social integration, I quantified the daily strength of association between the new individual and every other individual in the group using the affiliative behaviors. To do this, I calculated the Simple Ratio Index (SRI) (Whitehead, 2008). Here, a SRI closer to 1 indicates a higher association strength whereas a SRI closer to 0 represents a lower association strength. I smoothed the daily aggression rate and SRI values utilizing a rolling mean with a window of 3 days (sliding forward in steps of 1 day). Regarding aggressive interactions, I followed the same methodology as before, calculating the aggression rate but with daily values. This time, the focus was solely on interactions directed towards the new individual.

2.5 Statistical analysis

Identifying the phases of social integration involved determining breakpoints in both the total aggression rate and the SRI trajectories. The transition from exploration to pruning was established using the SRI trajectories while the aggression rate trajectory was used for defining the transition from the pruning phase to consolidation. This analysis was conducted using the 'changepoint' package, employing the PELT (Pruned Exact Linear Time) algorithm (Killick et al., 2022).

To evaluate the *befriend the dominant hypothesis*, I identified the daily strength of the social bonds (i.e., SRI values) of the new individual with every other individual in the group during the pruning and consolidation phases. For each phase, I fit a linear mixed model with the daily SRI values as a response variable, the dominance rank of the associated individual as a fixed factor while the group number and dyad were fit as random effects. Notably, dyad was treated as a nested random effect within the group. Models were done in the package 'lme4' (Bates et al., 2023). Additionally, for each model I calculated the effect size of the dominance ranks (with rank 1 as the baseline value) using Cohen's d. The interpretation of these effect sizes correspond to: small (d = 0.2), medium (d = 0.5), and large (d = 0.8) (Cohen, 1988).

To evaluate the *knowledgeable individual hypothesis*, I traced back the number of days it took for the integration to occur per group. The integration time is marked by the breakpoint that occurs in the aggression rate between pruning and consolidation which is also when there is a sudden decrease in the aggression rates towards the new individual. Afterwards, I conducted a Mann-Whitney U test to determine if there was a significant difference in integration time depending on the treatment.

3. RESULTS

I recorded a total of 8809 observations of affiliative behaviors and 1187 aggressive interactions for all dyads within the four groups during pretreatment (60 hours) and treatment (116 hours). In the case of missing videos, the number of hours was adjusted to the respective total. The affiliative social networks show that the mean affiliation rates dropped during treatment compared to pretreatment (Figure 2), indicating a decline in affiliative behaviors after introducing the new individual.

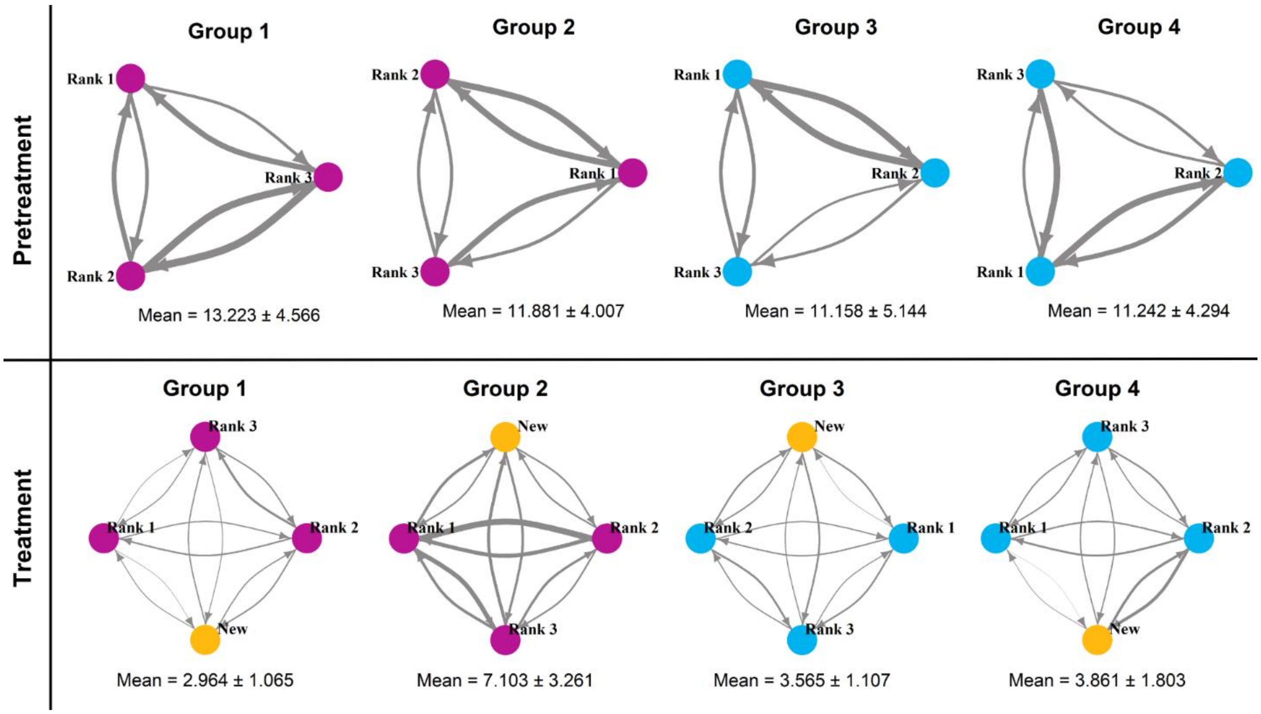

Figure 2. Affiliative directed and weighted networks for each experimental phase (pretreatment and treatment). Dots indicate individuals from the treatment (purple) and control (blue) conditions and the new individual (yellow). Edges represent the affiliation rate between dyads, determined by the duration of affiliative interactions. The mean and standard deviation values for the affiliation rate per group are reported below each network (mean ± SD).

Conversely, the aggression social networks illustrate an increase in aggression rates for all groups during treatment compared to the pre-treatment rates (Figure 3). This shows a shift towards heightened aggression following the introduction of the new individual.

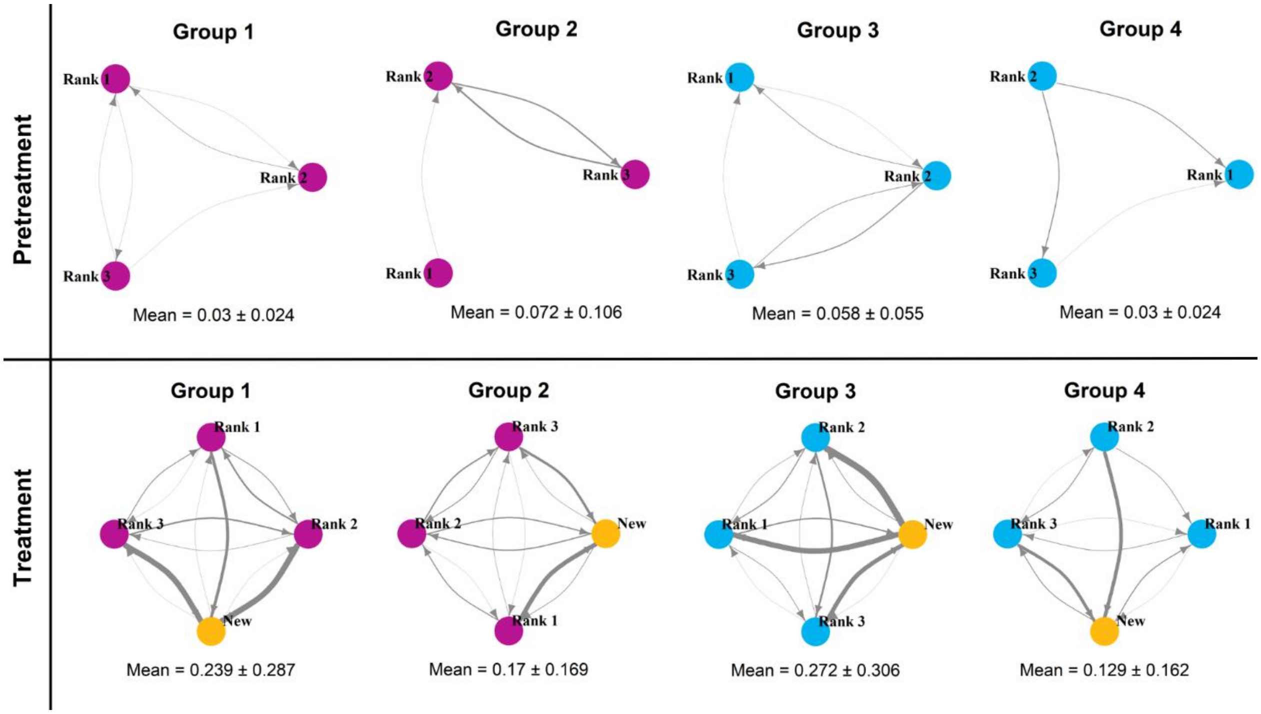

Figure 3. Aggression directed and weighted networks for each experimental phase (pretreatment and treatment). Dots indicate individuals from the treatment (purple) and control (blue) conditions and the new individual (yellow). Edges represent the aggression rate between dyads, determined by the number of aggressive interactions. The mean and standard deviation values for the aggression rate per group are reported below each network (mean ± SD).

The social integration process, shows a considerable variability within the same group and across groups, regardless of the treatment. The trajectory of association strength (SRI) of the new individual with every other member in all groups oscillated between 0.1 and 0.4 (Figure 4). At the beginning the focal individuals exhibited higher SRI values for rank 3 individuals across all groups. However, as time progresses, there is a larger variability between groups; yet, in groups 1 and 4 rank 2 individuals display higher peaks in association strength (Figure 4). Finally, when examining the overall trend of total association strength for each group (black dashed line in Figure 4), a clear pattern emerges — the bond strength of the new individuals tends to increase over time.

From the trajectory of the SRI, I could not detect I breakpoint that allowed the identification of the exploration phase; therefore, I used a visual criterion to define it as occurring during the first-time window. Because the exploration phase is defined as an active assessment of other individuals of the group, I used the first lowest value of the SRI soon after the new individual was introduced. This pattern was very clear for groups 1, 2, and 4 (Figure 4A, B and D) that exhibited a higher SRI during the first-time window compared to the second one, and less clear for group 3 (Figure 4C). Thus, I defined the exploration phase between days 1 and 3 of the treatment.

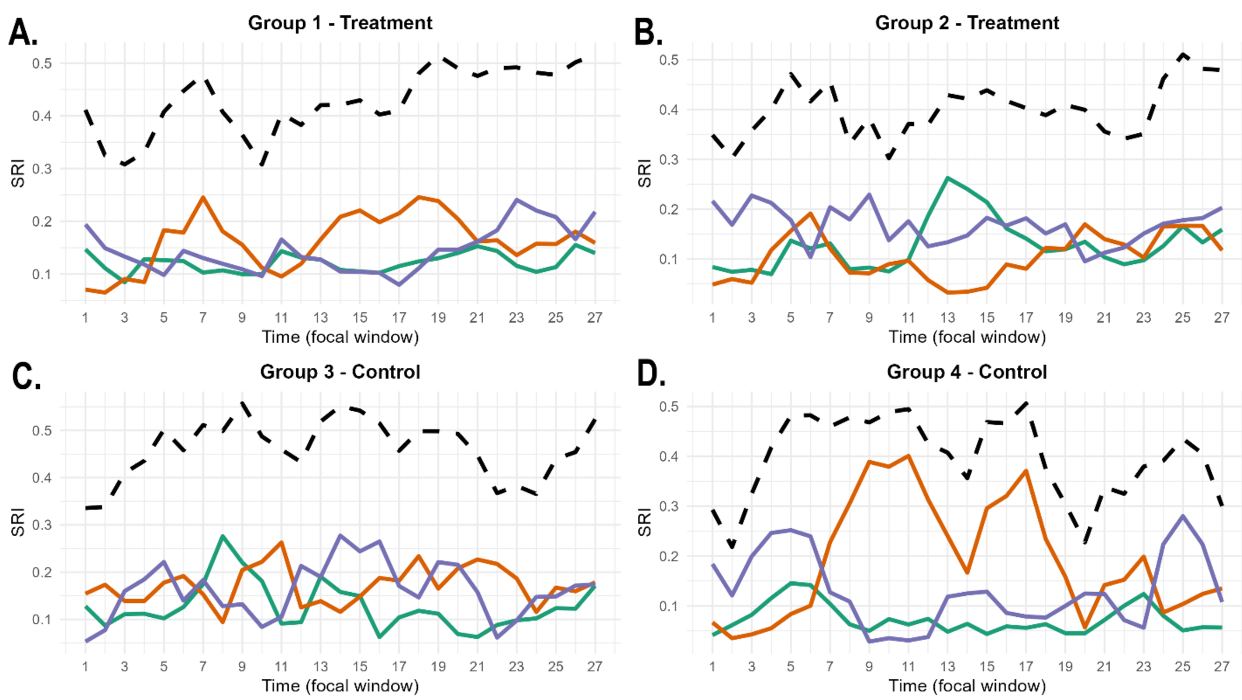

Figure 4. Association strength (SRI) trajectories of the new individual (focal). Each graph (A-D) represents the development of the pairwise association strength between the new individual and

all other individuals in the corresponding group. Line colors indicate the individuals of the already established group and their respective rank in the dominance hierarchy (blue = rank 1; orange = rank 2; purple = rank 3). The black dashed line indicates the total SRI for each group over time. The SRI for each focal window was calculated as the average strength in a 3-day rolling window, where focal window 1 refers to days 1–3.

The trajectory of aggression rates over time also shows large variation (Figure 5). When considering the total aggression rate (black dashed line) I identified a distinct trend. Initially, during the first focal windows, the aggression rate is at its highest, yet as time progresses, it decreases. The magenta line points out the breakpoint for the trajectory of each group and indicates the transition point from the pruning (duration varies from 2 to 5 days) to consolidation phase (duration varies from 22 to 24 days). This point marks a distinct moment in the dynamics of the social interaction process when the aggression drastically decreases, and the new individual starts forming long-lasting relationships with others.

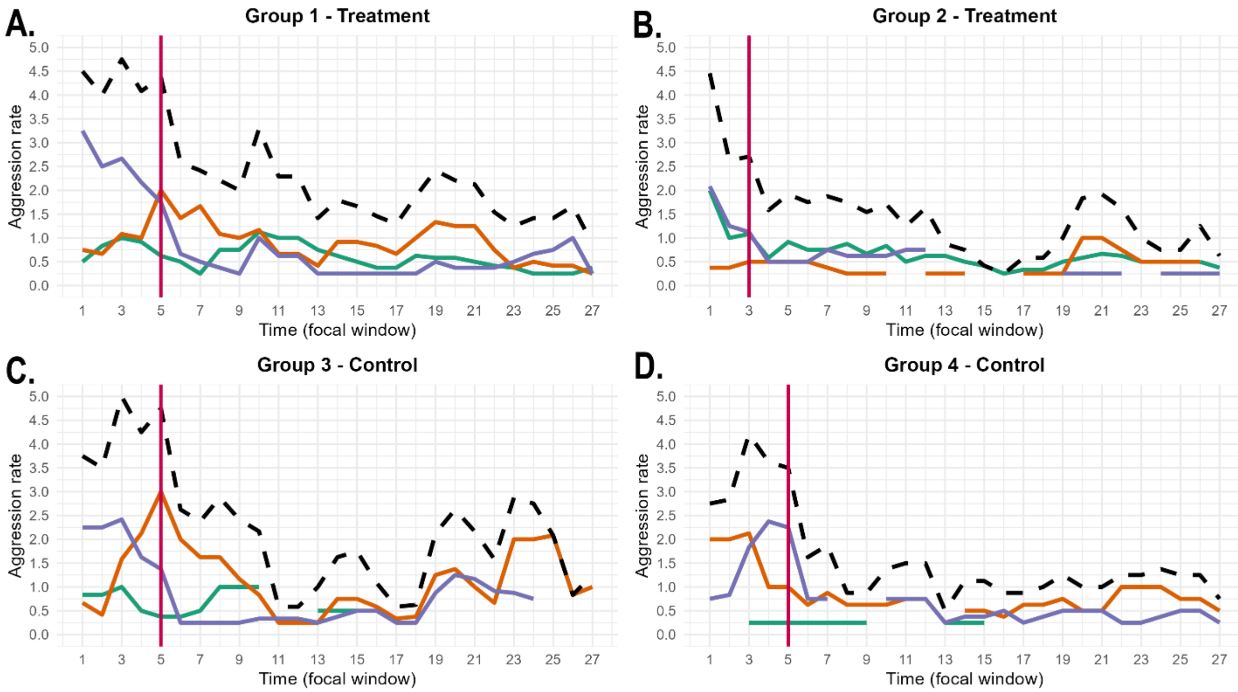

Figure 5. Aggression rate trajectories of the new individual (focal). Each graph (A-D) illustrates the aggression rate received by the new individual from all other individuals in the corresponding group. Line colors indicate the individuals of the already established group and their respective rank in the dominance hierarchy (blue = rank 1; orange = rank 2; purple = rank 3). The black dashed line shows the total aggression rate for each group, while the magenta line highlights at which window the breakpoint for the total aggression rate over time occurs. The aggression rate for each focal window was calculated as the average strength in a 3-day rolling window, where focal window 1 refers to days 1–3.

For the *dominant individual hypothesis*, the linear mixed models for pruning and consolidation phases suggest that there are no differences in the strength of the association (SRI) developed by the new individual with every other individual of the group (Table 1). In fact, as seen in Figure 4, individuals with rank 2 and 3 exhibited stronger relationships with the new individual, compared to the strength of the association with the individual of rank 1. Effect sizes indicate that, in the pruning phase, rank 3 exhibits a larger effect size (Cohen's d=2.1923) in comparison to rank 2 (Cohen's d=0.2339). In contrast, for consolidation phase, both rank 2 and 3 show substantial effect sizes in social bond strength with Cohen's d values of 2.0825 and 1.1768, respectively.

Table 1. Model coefficients and standard errors from linear mixed models evaluating the relationship between rank and daily SRI during the phases of pruning and consolidation. N corresponds to the total number of observations included in the model. *Denotes statistical significance at the P < 0.05 level.

	Pruning model (N=42)				**Consolidation model (N=263)**			
Random effects	**Variance**		**SD**		**Variance**		**SD**	
Dyad:Group	0.0004		0.0198		0.0010		0.0322	
Group	0.0000		0.0000		0.0000		0.0000	
Residuals	0.0072		0.0849		0.0082		0.0903	
Fixed effects	**Estimates**	**SE**	**t-value**	**P**	**Estimates**	**SE**	**t-value**	**P**
(Intercept)	0.1092	0.0249	4.393	0.0029*	0.1156	0.0188	6.157	0.0002*
Rank2	0.0082	0.0352	0.234	0.8215	0.0552	0.0265	2.082	0.0671
Rank3	0.0771	0.0352	2.192	0.0630	0.0312	0.0265	1.177	0.2695

For the knowledgeable *individual hypothesis* only one group in the treatment condition had a 5-day integration period, while the remaining groups followed a 7-day integration period (Figure 6). The comparison of integration times between the control and treatment conditions did not reveal a statistically significant difference (Mann-Whitney; P=0.6171) indicating that there are no differences in the integration time between the control and the treatment.

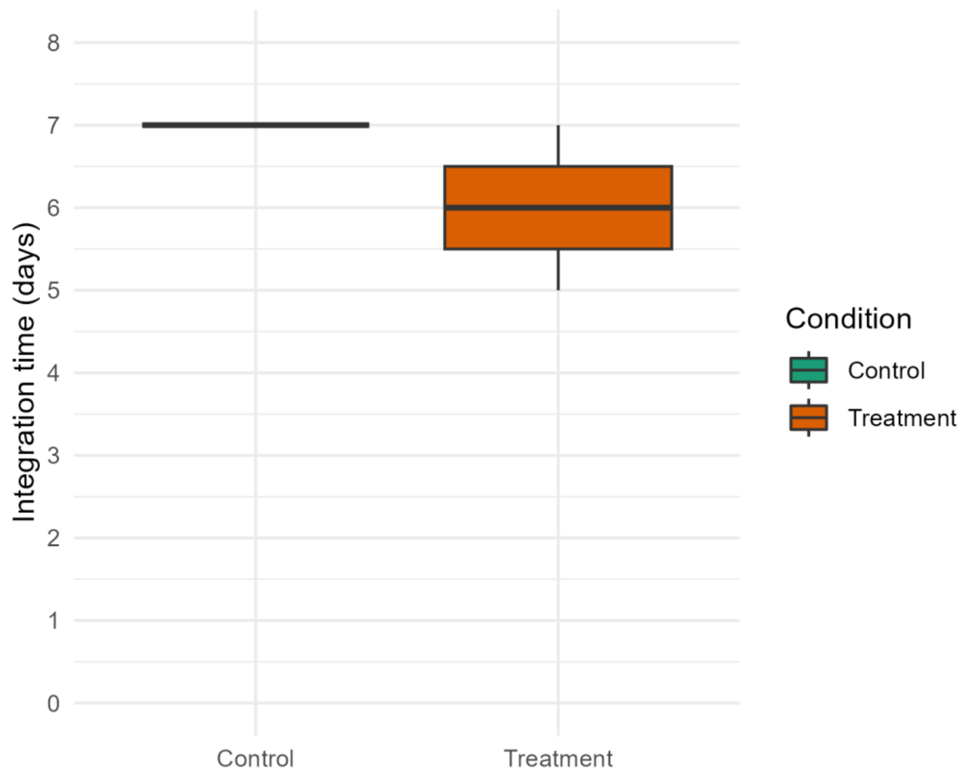

Figure 6. Time it took for the new individual to integrate into the established group for control (naïve individual) and treatment (knowledgeable individual) groups. The integration time was defined as the day that the change from pruning to consolidation occurred (there is a sudden decrease in the aggression rates).

4. DISCUSSION

Social integration is a key process during the life history of an individual, especially for group-living species. Here, the results show evidence for Kohn's (2019) three socialization phases during the social integration process. That is, the initial exploration phase is brief, marked by the new individual's attempts to establish affiliative interactions within the existing group. Subsequently, in the pruning phase there is a peak in aggression rates, leading to the final consolidation phase where social bonds strengthen and the aggression decreases. Furthermore, I did not find support for the *befriend the dominant hypothesis,* or the *knowledgeable individual hypothesis*. This indicates that the strategies that new individuals use to be accepted in a new and stable social group in guinea pigs differ from those proposed in primates, and thus they require further exploration.

The process of social integration is in line with Kohn's (2019) developmental framework on relationship formation. Although the initial framework is grounded in socialization during early life, the evidence found implies that these socialization phases can occur throughout an individual's life span in diverse ecological contexts like animal dispersal. First, during exploration, the new individual experiences interactions with different conspecifics. This initial contact coupled with individual-specific past experiences can shape the strategies as well as the type of bonds they form in the future (Kohn, 2019). For instance, studies in primates and birds have shown that a wider diversity of early-life interactions with novel individuals translates to the development of better social skills (Anderson & Mason, 1974; Ladd, 1999; Ladd et al., 2006; White et al., 2010). In the case of rodents, research on mice (*Mus musculus*) indicates that those with more early-life interactions with others exhibit more competent social behavior (Branchi, 2009). The variability observed throughout the integration process, both within and between groups, may be linked to the diverse social experiences animals accumulate over their lifetimes —a concept that warrants further investigation.

When introducing a new individual into a group, aggression is expected to increase among individuals within the groups (Camerlink et al., 2014; Poirier & Festa-Bianchet, 2018). This pattern was evident during the pruning phase, with aggression rates peaking before decreasing during the consolidation phase. However, it is noteworthy that sociopositive interactions happen simultaneously as they are necessary for the initial development of affiliative relationships (Kohn, 2019). For example, in *Forpus conspicillatus*, juveniles without siblings form affiliative bonds with unrelated conspecifics to start integrating into a social network (Wanker, 1999). This aligns with the observed trend in the pruning phase, where there is an increase in affiliative behaviors, while also aggressive behaviors are occurring. Moreover, as the new individual explores the wider peer group, there is a tendency for selectivity, restricting interactions towards a single peer—a phenomenon observed in species like *Melopsittacus undulatus* and *Forpus conspicillatus* (Garnetzke-Stollmann & Franck, 1991; Stamps et al., 1990). Due to this selectivity, some connections are strengthened while others are weakened over time. Hence, the dynamics of social relationships during pruning, where the new individual's behavior is directed towards specific individuals and away from others, play a pivotal role in elucidating the emergence of social relationships.

The consolidation phase, where the new individual maintains and strengthens connections within the group is supported by the increase over time of the social bond strength in all groups. Although Kohn's (2019) model proposes play behavior as a key component to establish social connections, these behaviors do not apply in an adult context. Rather affiliative behaviors such as social foraging, sitting in body contact, sitting in close proximity and grooming may play a key role in reinforcing the social connections chosen. Therefore, in the consolidation phase of social integration, adults reinforce social bonds through affiliative behaviors, deviating from the play-centric patterns observed in early-life socialization. It is crucial to consider the specific context and characteristics of the evaluated group to accurately interpret the dynamics of this phase.

The strategy of establishing social relationships with the dominant individual is believed to confer numerous advantages to the new individual, as the dominant individual can potentially serve as an ally in agonistic contexts (Matheson & Bernstein, 2000; Schino, 2001; Seyfarth, 1977, 1980). This is particularly evident during the initial stages of integration when aggression rates are notably high. Despite the evident benefits associated to this strategy, I did not find support for the *befriend the dominant hypothesis*. An explanation for this result could be linked to how grooming is regarded as a good index of affiliative relations among female primates and is used to illustrate the principles governing primate social structures (Carpenter, 1973; Schino, 2001). In contrast, grooming is an unusual behavior in the guinea pig, as it is sought by the initiator but usually avoided by the recipient (Willis et al., 1977). Moreover, there is not an established behavior indicative of affiliative interactions in this species, especially within only-female groups (Willis et al., 1977). Considering that the *befriend the dominant hypothesis* is based on Seyfarth's model of social grooming ─framed within primate dominance structures and social behavior─ it is reasonable to consider that in the context of social integration, guinea pigs might employ different strategies. Understanding the underlying factors that influence social integration in other groups can give insights to better identify the drivers of stability and flexibility in social composition and the wide variation in social organizations.

When interpreting the difference in effect sizes for each phase in the context of the *befriend the dominant hypothesis*, it is crucial to consider the limitations of the small sample size used for the analysis (Camerlink et al., 2014; Cant et al., 2001). Even with this constraint, the large effect sizes obtained indicate substantial and noteworthy differences in social bond strength between dominance ranks in the biological context. A notable observation, both visually and in effect size, is that during pruning, rank 3 exhibits the largest effect size, whereas during consolidation, the highest effect size is observed in rank 2. From these observations, I propose the *escalating between ranks hypothesis* for future investigation. Under this hypothesis, the new individual initially interacts more with individuals in the lowest rank and, as time progresses, 'escalates' to interact with individuals in higher ranks. This behavior aligns with studies on *Oreamnos americanus*, where individuals interact more frequently with those of similar ranks than those distant in the dominance hierarchy (Côté, 2000). The new individual seeking lower ranks at the start could be a strategic response to the high rates of aggression observed after the initial arrival.

Knowledgeable individuals tend to be more central in social networks and develop more cohesive bonds which could aid in accelerating the social integration process (Kulahci et al., 2016, 2018; Stammbach, 1988). However, I found that knowledgeable individuals arriving to an already established group did not integrate more rapidly than naïve ones. When considering the foraging task, it is important to acknowledge that while guinea pigs demonstrate social learning through interactions with conspecifics (Monfils & Agee, 2019), uncertainty surrounds their ability to assess unique characteristics in fellow individuals, such as the possession of novel knowledge. A notable contrast exists with *Macaca fascicularis*, as group members are aware of the skills other individuals have and adapt their behavior accordingly to maximize benefits from those skills (Stammbach, 1988). Consequently, the results obtained for the integration time could be a byproduct of the ability of guinea pigs to socially learn, but not necessarily lead to a change in their behavior if they cannot identify the advantage the knowledgeable individual has. Thus, considering the ecological context where the integration takes place, as well as the cognitive abilities of the study system would contribute to future studies and enhance the robustness of results.

My findings conform to Kohn's (2019) developmental model, showing that the phases of exploration, pruning and consolidation occur in the context of animal dispersal. Although new individuals did not exhibit a preference for the dominant individual, nor did the integration occur faster if the new individual possessed novel knowledge, there are still other factors at play during social integration that remain to be explored. Understanding the underlying mechanisms and strategies of social integration warrants much greater consideration. After all, initial interactions between individuals can reflect species-typical social behavior and provide insights into aspects of social organization, thus, shedding light on the evolution of sociality and life history in various groups. Additionally, the exploration of social integration holds practical applications in wildlife management. In the end, the knowledge gleaned in terms of behavior, expected integration times and possible strategies to speed up the process can be a valuable asset for the reintegration of individuals in conservation scenarios (Gusset et al., 2006; Poirier & Festa-Bianchet, 2018).

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